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CaseNumber: WR-72,702-02

EventDate: 08/22/2011

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WRIT I

CLERK'S RECORD

VOLUME 3

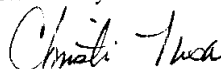
The State of Texas

vs.

MELISSA ELIZABETH LUCIO

Mailed to the Court of Criminal Appeals on
MARCH 30, 2011

Aurora De La Garza
Cameron County District Clerk


CHRISTINA TUSA
Deputy Clerk

Filed in the Court of Criminal Appeals, at Austin, Texas
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Louise Pearson.
Clerk of Court of Criminal Appeals

Deputy

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No. 07-CR-885-B
Writ No. _____

IN THE
138th JUDICIAL DISTRICT COURT OF
CAMERON COUNTY, TEXAS

and

THE TEXAS COURT OF CRIMINAL APPEALS

Ex Parte MELISSA ELIZABETH LUCIO,
Applicant

APPENDIX
TO APPLICATION FOR WRIT OF HABEAS CORPUS
PURSUANT TO SECTION 4 OF ARTICLE 11.071 OF
THE TEXAS CODE OF CRIMINAL PROCEDURE

VOLUME 2 OF 5

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Washington University Law Review

VOLUME 87

NUMBER 1

2009

THE NEXT INNOCENCE PROJECT: SHAKEN BABY SYNDROME AND THE CRIMINAL COURTS

DEBORAH TUERKHEIMER*

Every year in this country, hundreds of people are convicted of having shaken a baby, most often to death. In a prosecution paradigm without precedent, expert medical testimony is used to establish that a crime occurred, that the defendant caused the infant's death by shaking, and that the shaking was sufficiently forceful to constitute depraved indifference to human life. Shaken Baby Syndrome (SBS) is, in essence, a medical diagnosis of murder, one based solely on the presence of a diagnostic triad: retinal bleeding, bleeding in the protective layer of the brain, and brain swelling.

New scientific research has cast doubt on the forensic significance of this triad, thereby undermining the foundations of thousands of SBS convictions. Outside the United States, this scientific evolution has prompted systemic reevaluations of the prosecutorial paradigm. In contrast, our criminal justice system has failed to absorb the latest scientific knowledge. This is beginning to change, yet the response has been halting and inconsistent. To this day, triad-based convictions continue to be affirmed, and new prosecutions commenced, as a matter of course.

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This Article identifies a criminal justice crisis and begins a conversation about its proper resolution. The conceptual implications of the inquiry—for scientific engagement in law's shadow, for future systemic reform, and for our understanding of innocence in a post-DNA world—should assist in the task of righting past wrongs and averting further injustice.

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I. INTRODUCTION

Natalie Beard died on October 16, 1995.¹ That morning, her mother had brought the seven-month-old to the home of her day care provider, Audrey Edmunds.² The baby was by all accounts fussy.³ According to the caregiver's account, shortly after the baby was delivered to her, Edmunds

1. State v. Edmunds, 598 N.W.2d 290, 293 (Wis. Ct. App. 1999).

2. *Id.*

3. *Id.*

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propped Natalie in her car seat with a bottle,⁴ left the room, and returned a half-hour later to discover her limp.⁵ Edmunds—herself a mother—immediately called 911 to report that Natalie appeared to have choked and was unresponsive.⁶ Rescue workers responded minutes later and flew the baby to the hospital, where she died that night.⁷

Prosecutors charged Edmunds with murder based on the theory that Natalie had been shaken to death.⁸ No witness claimed to have seen the defendant shake the baby.⁹ There were no apparent indicia of trauma.¹⁰ Edmunds maintained her innocence throughout.¹¹ Yet a jury convicted Edmunds on the sole basis of expert testimony that Natalie suffered from Shaken Baby Syndrome (SBS).¹² A court sentenced Edmunds to eighteen years in prison.¹³

In important respects, this case falls squarely within the “shaken baby” prosecution paradigm that developed in the early 1990s. The infant¹⁴ had no external injuries suggestive of abuse.¹⁵ The accused¹⁶ was unable to

4. Brief of Defendant-Appellant at 4–5, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Ct. App. 2008) (No. 2007AP000933).

5. *Id.*

6. *Id.*

7. *State v. Edmunds*, 598 N.W.2d at 293.

8. Edmunds was charged with reckless homicide in the first degree, *id.*, which required the prosecution to prove that she disregarded an “unreasonable and substantial risk of death or great bodily harm” under circumstances evidencing an “utter disregard for human life,” *id.* at 295.

9. *Id.* at 293–94.

10. *Id.*

11. *Id.* at 293.

12. *Id.*

13. Emphasizing the lack of any evidence that “the severe injuries Natalie sustained could have been the result of an accident, rather than intentional, forceful conduct, directed specifically at Natalie,” the appellate court affirmed Edmunds’s conviction. *Id.* at 294. After exhausting her state remedies, Edmunds petitioned for federal habeas corpus review, which was denied. *Edmunds v. Deppisch*, 313 F.3d 997 (7th Cir. 2002).

14. The average age of infants diagnosed with SBS is between three months and ten months, though children up to three-years-old have been diagnosed. Stephen C. Boos, *Abusive Head Trauma as a Medical Diagnosis*, in *ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN: A MEDICAL, LEGAL, AND FORENSIC REFERENCE* 49, 50 (Lori Frasier et al. eds., 2006).

15. In a typical case, an infant “is brought to the emergency room with the sudden onset of unconsciousness and respiratory irregularities or seizure. The given history suggests sudden and unprovoked symptoms . . . [b]ut there is no external evidence to indicate that trauma caused their ailment.” *Id.*

16. The oft-quoted hierarchy of suspected perpetrators of head injury describes fathers as the most likely abusers, followed by mothers’ boyfriends, and unrelated female babysitters. *Id.* at 62. Regarding the social risk factors for child abuse generally, “[y]oung unmarried parents, lack of education, low socioeconomic status, minority status, and many other risk factors have been shown to predict increased child abuse rates. However . . . [a]pplying population variables to individual cases of child abuse may be misleading, and has led to the overassessment of minority populations.” *Id.* at 62.

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provide an explanation for the child's condition.¹⁷ The medical evidence against the defendant consisted of the three diagnostic symptoms comprising the classic "triad": retinal hemorrhages (bleeding of the inside surface of the back of the eye); subdural hemorrhages (bleeding between the hard outer layer and the spongy membranes that surround the brain); and cerebral edema (brain swelling).¹⁸ The presence of these three signs was understood to be pathognomic—or exclusively characteristic—of SBS.

At trial, the prosecution's experts testified that "only shaking, possibly accompanied by impact" could explain the injuries.¹⁹ Regarding the force necessary to cause these injuries, jurors heard the explanation typically offered in these cases: the force was equivalent to a fall from a second- or third-story window, or impact by a car moving at twenty-five to thirty miles an hour.²⁰ The prosecution's experts concluded that the shaking necessarily occurred while the baby was in the defendant's care, since the trauma of the shaking would have caused immediate unconsciousness.²¹ The scientific basis for SBS was not challenged by the defense.²² And

17. See *infra* notes 181–82 and accompanying text.

18. Brief of Defendant, *supra* note 4, at 5. For discussion of the classic SBS triad, see, for example, Comm. on Child Abuse and Neglect, Am. Acad. of Pediatrics, *Shaken Baby Syndrome: Rotational Cranial Injuries—Technical Report*, 108 PEDIATRICS 206 (2001); Mary E. Case et al., The Nat'l Ass'n of Med. Exam'rs Ad Hoc Comm. on Shaken Baby Syndrome, *Position Paper on Fatal Abusive Head Injuries in Infants and Young Children*, 22 AM. J. FORENSIC MED. & PATHOLOGY 112 (2001). See also Part III.B.1, *infra* notes 60–64 and accompanying text (elaborating on significance of diagnostic triad).

19. Brief of Defendant, *supra* note 4, at 6. See *infra* notes 60–64 and accompanying text (discussing how shaking is thought to cause triad of symptoms).

20. Brief of Defendant, *supra* note 4, at 7. According to the American Academy of Pediatrics, "[t]he act of shaking leading to shaken baby syndrome is so violent that individuals observing it would recognize it as dangerous and likely to kill the child." Am. Acad. of Pediatrics, *supra* note 18, at 206. Prosecution experts have often amplified this type of testimony with in-court demonstrations of the force believed to be necessary to inflict the brain injuries. For a computerized demonstration of this kind see Expert Digital Solutions, Inc., *Shaken Baby*, <http://www.expertdigital.com/shakenbaby.html>. See *infra* note 256 (noting reversal of convictions on this basis). But see *People v. Mora*, 868 N.Y.S.2d 722, 723 (N.Y. App. Div. 2008) (trial court "providently exercised its discretion" in allowing prosecution's expert to "shake his coat in order to demonstrate the amount of force necessary to inflict Shaken Baby Syndrome").

21. Brief of Defendant, *supra* note 4, at 8.

22. "Edmunds presented one medical expert witness who agreed with the State's witnesses that Natalie was violently shaken before her death but who opined that the injury occurred before Natalie was brought to Edmunds's home." *State v. Edmunds*, 2008 WI App 33, ¶ 3, 746 N.W.2d 590, ¶ 3. Edmunds's theory was that one or both of the parents had shaken Natalie the night before her death. *Edmunds v. Deppisch*, 313 F.3d 997, 998 (7th Cir. 2002). This (failure to identify the correct perpetrator) has been a common defense in shaken baby prosecutions, as has the argument that, if the defendant shook the baby, the shaking did not achieve the level of force necessary to sustain a murder conviction. See *infra* note 181 and accompanying text (describing most common caregiver accounts).

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indeed, at the time of Edmunds's trial, the medical consensus on this issue was overwhelming.²³

All of this is standard fare for an SBS prosecution.²⁴ With rare exception, the case turns on the testimony of medical experts. Unlike any other category of prosecution, all elements of the crime—*mens rea* and *actus reus* (which includes both the act itself and causation of the resulting harm)—are proven by the science. Degree of force testimony not only establishes causation, but also the requisite state of mind.²⁵ Unequivocal testimony regarding timing—i.e., that symptoms necessarily would appear instantaneously upon the infliction of injury—proves the perpetrator's identity. In its classic formulation, SBS comes as close as one could imagine to a medical diagnosis of murder: prosecutors use it to prove the mechanism of death, the intent to harm, and the identity of the killer.

Edmunds is a representative shaken baby case in every respect but one. On January 31, 2008, Audrey Edmunds was granted a new trial on the basis of an evolution in scientific thinking. For the first time, a court examining the foundation of SBS concluded that it had become sufficiently eroded that a new jury probably would have a reasonable doubt as to the defendant's guilt.²⁶ According to the court, "a shift in mainstream medical opinion"²⁷ had undermined the basis of the SBS diagnosis, raising the distinct possibility that Edmunds, who was still serving her eighteen-year sentence in Wisconsin, had done nothing whatsoever to harm the child. As is true of an unknown number of

23. *State v. Edmunds*, No. 96 CF 555, slip op. at 5 (Wis. Cir. Ct. Mar. 29, 2007) ("The medical evidence was largely consistent and unchallenged."). See Brief of Defendant, *supra* note 4, at 9 (discussing unanimity of medical opinions and state's reliance on this in argument to jury).

24. Once a child protection team has made an SBS diagnosis, suspected perpetrators—those with the child when symptoms appeared—are aggressively prosecuted. Each year, an estimated thousand plus defendants are convicted, most of murder, annually. Toni Blake, Jury Consultant, Address at the Forensic Truth Foundation: When Hypothesis and Data Conflict: An Analysis of an Infant Injury Database (May 12–15, 2007) (estimating that 95% of defendants prosecuted in SBS cases are convicted and 90% are serving life sentences).

25. "A key component of any expert testimony on SBS involves translating the mechanism of trauma into constructs . . . which adequately reflect the *mens rea* requirements for the charge." Brian Holmgren, *Prosecuting the Shaken Infant Case*, in *THE SHAKEN BABY SYNDROME: A MULTIDISCIPLINARY APPROACH* 275, 307 (Stephen Lazoritz & Vincent J. Palusci eds., 2001). As the prosecutor in *Edmunds* argued on summation, "one can only imagine the anger and the intensity of the shaking that goes on and the impact that goes on in these cases." Brief of Defendant, *supra* note 4, at 8. Evidence of force was thus used to establish that the defendant was reckless and exhibited utter disregard for human life.

26. *Edmunds*, 746 N.W.2d at 599.

27. *Id.* at 598–99.

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convictions like it,²⁸ the science upon which the defendant's conviction rested had advanced, raising the specter of innocence.

This Article explores what ensues when medical certainty underlying science-based prosecutions dissipates.²⁹ It asks how a scientific revolution penetrates the criminal justice system and whether our legal system effectively responds to the inevitable consequences of science outpacing the law. The remarkable transformation of SBS provides a unique vehicle for probing these questions.

This examination begins in Part II, which places SBS prosecution in historical context, exposing the recent and rapid ascendance of a paradigm that, until now, has gone largely unnoticed.³⁰

Part III assesses the current scientific controversy. A critical look at the creation of SBS exposes a diagnosis flawed from its inception by a tainted methodological approach, one, in all likelihood, corrupted by a too-close medical-legal nexus.³¹ In recent decades, researchers have uncovered these failings, and the diagnosis has evolved accordingly. There is now general agreement among the medical community that the previous incarnation of SBS is invalid.³² The particulars of this evolution are striking—especially from a criminal justice standpoint. Despite continued controversy around aspects of the diagnosis, Part III identifies a number of key areas where the framework for debate itself has been significantly altered. This discussion reveals that the new SBS is different enough from what came before to raise serious challenges to a substantial number of criminal convictions.

Specifically, these scientific developments have cast into doubt the guilt of an entire category of defendants: those convicted of crimes based on a triad-only SBS diagnosis. While we cannot know how many convictions are “unsafe” without systematic case review, a comparison of the problematic category of SBS convictions to DNA—and other mass

28. See *infra* Part II.

29. This Article focuses on the criminal justice system's treatment of SBS. It should be noted that SBS's evolution also has powerful family court implications. See, e.g., *In re J.S.*, 785 A.2d 1041 (Pa. Super. Ct. 2001) (affirming removal of two-month-old child and his sibling based on questionable SBS diagnosis).

30. No legal scholar has attended to the proliferation of SBS prosecutions or explored the strange trajectory of SBS in science and law. This project has been given new urgency by mounting challenges to the validity of the science upon which these cases rest. At this moment, when new perspectives on old science are only just beginning to penetrate the criminal justice system, the emergence of a scholarly treatment of SBS and the law is especially critical.

31. See *infra* Part III.A.

32. See *infra* Part III.B.

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exonerations—reveals that this injustice is commensurate with any seen in the criminal justice arena to date.³³

Part IV chronicles the criminal justice system's treatment of the changing science. I do so by surveying the various stages in the criminal process where actors make decisions with the potential to account for—or overlook—scientific developments of the past decade. Police and prosecutors investigate cases and prosecutors decide whether to pursue charges.³⁴ Defendants and prosecutors make *Daubert* and *Frye* challenges to the admissibility of scientific evidence.³⁵ Jurors determine whether guilt has been proven beyond a reasonable doubt.³⁶ Defendants appeal and collaterally attack their convictions based on insufficiency of the evidence.³⁷ And defendants make motions for post-conviction relief because new evidence has been discovered.³⁸

This procedural approach to understanding how the law integrates new scientific knowledge uncovers a response that is halting and inconsistent. I focus my critique on the system's treatment of cases in which SBS diagnoses rest on outmoded medical dogma. What can be discerned about the status quo is alarming. Guilt is being assigned where the best available science creates, at the very least, reasonable doubt. When an outcome reflecting the best available science is generated, it is not because the factual predicate for the prosecution diverges from the typical case but, rather, because the defendant is able to mount an aggressive attack—one that requires resources—on a body of science whose vulnerability is, in theory, equally exposed to all.

In short, prosecutors and courts are differentially absorbing scientific developments, resulting in an arbitrary distribution of justice.³⁹ Since

33. See *infra* notes 142–47 and accompanying text.

34. See *infra* Part IV.A. My own intuitions about this phase of the criminal process are informed by my experiences prosecuting child abuse cases as an Assistant District Attorney in the Family Violence Bureau of the New York County District Attorney's Office.

35. See *infra* Part IV.B.

36. See *infra* Part IV.C.

37. See *infra* Part IV.D.

38. See *infra* Part IV.E.

39. The same week *Edmunds* was decided, an appeals court in Arkansas decided the appeal of Samantha Anne Mitchell, an in-home daycare provider for a four-month-old infant. *Mitchell v. State*, No. CACR 07-472, 2008 Ark. App. LEXIS 98, at *1 (Ark. Ct. App. Feb. 6, 2008). The baby died of what prosecution experts diagnosed as SBS based on the presence of the classic triad of symptoms (again, subdural hemorrhaging, brain swelling, and retinal hemorrhages)—the same triad that convicted Audrey Edmunds. *Id.* at *5–6. In terms of the medical findings and the prosecution's legal theory, the cases are remarkably similar. Yet the very week that Audrey Edmunds was awarded a new trial, leading prosecutors in Wisconsin ultimately to dismiss the charges against her, Samantha Anne Mitchell's murder conviction was affirmed. *Id.* at *10.

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January 31, 2008, when Edmunds's new trial motion was granted, dozens of convictions based on SBS have been upheld, either on direct appeal or collateral attack. An unknown number of prosecutions have been initiated and an unknown number resulted in convictions.⁴⁰ While a portion of these cases rely on corroborating medical evidence of injury beyond the triad,⁴¹ many do not.

The story of our legal system's response to SBS speaks to how crime is constructed and reified. It tells of institutional inertia and a quest for finality⁴² that sit uneasily with our commitment to justice. And it demands consideration of where we go from here. By identifying a problem of tragic dimensions, I hope to begin a conversation that seeks solutions and situates itself in the emerging discourse on innocence.⁴³ The conceptual implications of this inquiry—for scientific engagement in law's shadow, for future systemic reform, and for the notion of innocence in a post-DNA world—should assist in the task of righting past wrongs and averting further injustice.

40. See, e.g., Shane Anthony, *Nanny Should Get 7 Years in Prison, Jury Says Woman, 22, was Convicted of Assaulting 4-Month-Old Boy*, ST. LOUIS POST-DISPATCH, July 30, 2008, at B1; Rebecca Baker, *Greenburgh Nanny Pleads Guilty in Shaken-Baby Case*, THE JOURNAL NEWS (N.Y.), July 30, 2008, available at <http://m.lohud.com/news.jsp?key=110532>; Sarah Kapis, *Stonewood Father Arrested in Shaken Baby Case*, W. VA. MEDIA, June 23, 2008, http://www.wboy.com/story.cfm?func=view_story&storyid=40376; Robert Kerns, *Inquest Jury Rules Infant's Death as Homicide by Shaken Baby Syndrome*, PEKIN DAILY TIMES (Ill.), June 13, 2008, available at <http://www.pekintimes.com/articles/2008/06/13/news5.txt> (on file with author); T.C. Mitchell, *Father Pleads Guilty to Infant Daughter's Killing*, ANCHORAGE DAILY NEWS, Aug. 11, 2008; Molly Montag, *Daycare Provider Faces Charges for Injured Infant*, SIOUX CITY J., July 3, 2008, available at <http://www.siouxcityjournal.com>; Andy Nelesen, *Tot Hit Head in Tub, Murder Suspect Tells Police*, GREEN BAY PRESS GAZETTE, June 20, 2008; Jamaal E. O'Neal, *Man Charged with Felony in Baby's Injury*, LONGVIEW NEWS-JOURNAL (Tex.), Aug. 12, 2008, at 1B; Mona Ridder, *Grand Jury: Neglect Results in Child's Death*, CUMBERLAND TIMES-NEWS, June 25, 2008, available at http://www.times-news.com/local/local_story_177093757.html; Amy Upshaw, *Eudora Foster Mother of Dead Toddler Released on Bond*, ARK. DEMOCRAT GAZETTE, Aug. 13, 2008.

41. By one nationally prominent defense expert's account, one quarter of the cases prosecuted as SBS involve a "battered baby," or a child with substantial medical corroboration of physical abuse. Telephone Interview with John Plunkett, Retired Pathologist (June 20, 2008).

42. This quest is nicely evidenced by a Connecticut trial court's expression of concern in the wake of *Edmunds*: "the *Edmunds* case presents a potential quagmire of epic proportions: the strong likelihood of constant renewed prosecution and relitigation of criminal charges as expert opinion changes and/or evolves over time." *Grant v. Warden*, No. TSRCV03004233S, 2008 WL 2447272, at *1 n.1 (Conn. Super. Ct. June 4, 2008).

43. See *infra* Part V.

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II. THE AGE OF SBS

The first appeal of an SBS-related conviction was reported in 1984.⁴⁴ Based on the presence of bilateral retinal hemorrhages and subdural hematoma, the prosecution's expert concluded that a four-month-old infant had been shaken to death,⁴⁵ and the appellate court affirmed the sufficiency of the evidence to convict.⁴⁶ Over the next five years, less than fifteen appeals of convictions based on an SBS diagnosis were reported.⁴⁷

Beginning in 1990, however, the number of appeals grew dramatically. In five-year increments, published appellate decisions increased from 74 (January 1, 1990–December 31, 1994), to 160 (January 1, 1995–December 31, 1999), to 315 (January 1, 2000–December 31, 2004).⁴⁸ The numbers from the first half of the current five-year period suggest that this trend toward rising SBS appeals is continuing: from January 1, 2005 to June 30, 2008, 259 written opinions in this category were issued.⁴⁹

Appellate case law is admittedly an inadequate measure of prosecutions, both because most convictions do not result in a written appellate decision,⁵⁰ and because not all prosecutions result in conviction. Notwithstanding these limitations, the appellate case law can suggest, as it does in this instance, that the total volume of prosecutions has been on a sharply upward trajectory since 1990.

Ascertaining the absolute number of SBS prosecutions is of course far more difficult.⁵¹ Approximately 1500 babies are diagnosed with SBS in

44. *Ohio v. Schneider*, No. L-84-214, 1984 Ohio App. LEXIS 11988 (Ohio Ct. App. Dec. 21, 1984). For an overview of the diagnostic origins of SBS, see *infra* notes 60–64 and accompanying text.

45. *Schneider*, 1984 Ohio App. LEXIS 11988 at *3–4. At trial, the defense expert cited disagreement among scientists as to the quantity of force necessary to produce the observed injuries:

There are several articles which suggest that just playing with your child and throwing him up and down in the air when they are small infants, the reason infants are very risky incidences, they have very small bodies and large heads so the head tends to flop back and forth. Many people play with their children and throw up and down in the air and there are several experts suggesting that that definitely should not occur because it can cause small areas of brain damage and therefore injure your child. There really is no real documentation of whether or not a tremendous amount of force or several episodes can severely damage an infant.

Id. at *5. The defendant was convicted by jury of involuntary manslaughter. *Id.* at *1.

46. *Id.* at *14.

47. Based on culling results of search of “‘shaken baby’ and convict!”

48. *Id.*

49. *Id.*

50. According to Sam Gross, a leading expert on wrongful convictions, it would be conservative to estimate that, in this context, there are at least twice as many trial convictions as appeals, which would represent a higher incidence of appeals than average. Telephone Interview with Samuel Gross, Thomas and Mabel Long Professor of Law, Univ. of Mich. (July 21, 2008).

51. Media accounts tell of SBS prosecutions commencing daily across the country. See *supra* note 40. Given the number of SBS diagnoses made each year, see text accompanying *infra* note 52,

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the United States each year.⁵² How many of these cases result in prosecution and conviction is unknown, however, since no comprehensive data on SBS cases has ever been collected.⁵³ That said, there are a number of ways to estimate the magnitude of defendants potentially impacted by recent scientific developments.⁵⁴ One might conservatively assume that the approximately 800 appeals reported since 1990 reflect about 1500 convictions after trial.⁵⁵ To focus on more recent figures only, it seems fair to conclude that around 200 defendants a year are being convicted of SBS.⁵⁶ Without additional data, we cannot reasonably speculate about the number of defendants who plead guilty to this type of crime,⁵⁷ although the estimated 1500 SBS diagnoses a year may provide an outside parameter.

When placed against the backdrop of recent scientific developments, these numbers reflect a crisis in the criminal justice system.

III. SCIENTIFIC EVOLUTION

As a categorical matter, the science of SBS can no longer support a finding of proof beyond a reasonable doubt in triad-only cases⁵⁸—cases

this comes as no surprise.

52. Blake, *supra* note 24. See also Nat'l Shaken Baby Coal., *Facts About SBS!!!*, <http://www.shakenbabycoalition.org/facts.htm> (last visited July 13, 2009) ("Experts say 1,000–1,500 cases of SBS occur each year in the United States, but the true number of cases is unknown because of misdiagnoses and underreporting").

53. This void has allowed the phenomenal aspects of SBS prosecutions to remain largely obscured.

54. See *infra* note 58 (noting that not all SBS convictions have been undermined); *infra* note 143.

55. See *supra* note 50. But national trial consultant Toni Blake has herself been contacted by 2000 to 3000 lawyers over the past decade regarding assistance with SBS trials and appeals, suggesting that the actual number of trial convictions is significantly higher. Mark Anderson, *Does Shaken Baby Syndrome Really Exist?*, DISCOVER, Dec. 2, 2008, <http://discovermagazine.com/2008/dec/02-does-shaken-baby-syndrome-really-exist>.

56. This estimate is based on the number of reported decisions from January 1, 2005 through June 30, 2008 (259) and a multiplier of two. See *supra* note 50 [Sam Gross's conservative assumption].

57. According to Andrea Lyon, a law professor with experience representing clients in SBS cases, pleas in this type of prosecution are very much the norm given the likelihood that a jury will convict, see *infra* Part IV.C, and the almost certain harshness of a post-trial sentence. Interview with Andrea D. Lyon, Assoc. Dean for Clinical Programs and Clinical Professor of Law, DePaul Univ. Coll. of Law, in Chi., Ill. (Oct. 16, 2008). A similar sentiment was voiced by one public defender, who articulated the dilemma faced by his SBS client: "if he went to trial and lost, [the sentence] was either 20 to 50 years, 20 years to life, or life without parole. Agreeing to confess to shaking the child . . . would considerably reduce any sentence." Anderson, *supra* note 55. See *infra* note 150 (noting Ontario's Goudge Commission recommendations regarding review of guilty pleas).

58. By this, I mean those whose convictions rest exclusively on the presence of retinal hemorrhage and/or subdural hematomas. In contrast, a sizeable number of SBS prosecutions rely on

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which represent a significant number of SBS prosecutions. Put simply, here “change has raised the real possibility of past error.”⁵⁹

In the past, the mere presence of retinal hemorrhaging, subdural hematoma, and cerebral edema was taken to mean that a baby had been shaken hard enough to produce what were conceptualized as whiplash forces.⁶⁰ According to the conventional understanding of SBS,⁶¹ “[t]he application of rotational acceleration and deceleration forces to the infant’s head causes the brain to rotate in the skull. Abrupt deceleration allows continuing brain rotation until bridging veins are stretched and ruptured, causing a thin layer of subdural haemorrhage on the surface of the brain.”⁶² Retinal hemorrhages were thought to result from a similar causal mechanism.⁶³ Most significantly, the triad of symptoms was believed to be distinctly characteristic—in scientific terms, pathognomonic—of violent shaking.⁶⁴

Despite its lingering presence in the popular imagination, the scientific underpinnings of SBS have crumbled over the past decade⁶⁵ as the medical establishment has deliberately discarded a diagnosis defined by shaking.⁶⁶ Although no single nomenclature has emerged in its place,⁶⁷ doctors are now in widespread agreement that SBS is an unhelpful characterization,⁶⁸

corroborative evidence beyond the triad; convictions which result in these cases are therefore less dramatically undermined by recent scientific developments. *See infra* note 143. It should be noted that what constitutes real, as opposed to apparent, “corroboration” in SBS cases is often a difficult question. *See infra* notes 80–82, 181–90 and accompanying text (challenging validity of perpetrator “confessions”); *infra* note 146 (critiquing United Kingdom Attorney General’s definition of corroboration). *See also* Stein v. Eberlin, No. 1:07CV3696, 2009 WL 650363 (N.D. Ohio Mar. 10, 2009) (defense expert opined that “parietal cranial irregularities in the victim’s skull likely represent suture variants rather than fractures”); P. Weir et al., *Normal Skull Suture Variant Mimicking Intentional Injury*, 332 BRIT. MED. J. 1020 (2006). Nevertheless, this Article focuses on those cases predicated on the “pure triad,” or triad-only prosecutions.

59. STEPHEN T. GOUDGE, *INQUIRY INTO PEDIATRIC FORENSIC PATHOLOGY IN ONTARIO* 531 (Ontario Ministry of the Att’y Gen. 2008) (on file with author).

60. *See, e.g.*, John Caffey, *On the Theory and Practice of Shaking Infants*, 124 AM. J. DISEASES CHILDREN 161 (1972); Mary E. Case et al., *supra* note 18.

61. The term “came into general usage in the 1980s.” Robert Reece, *What Are We Trying to Measure: The Problems of Case Ascertainment*, 34 AM. J. PREVENTATIVE MED. S116 (2008).

62. Brian Harding, R. Anthony Risdon, & Henry F. Krous, Letter, *Shaken Baby Syndrome*, 328 BRIT. MED. J. 720, 720 (2004).

63. *Id.*

64. *See infra* Part III.A.

65. *See infra* Part III.B.

66. *See infra* Part III.B.3. This move away from etiological diagnosis toward anatomical diagnosis reflects a key concession to the limits of medical science. Telephone Interview with Stephen Boos, Dep’t of Pediatrics, Armed Forces Ctr. for Child Prot., Nat’l Naval Med. Ctr. (June 17, 2008).

67. Reece, *supra* note 61, at S116 (noting “lack of common nomenclature”).

68. “SBS” has been supplanted by a number of different terms: shaken impact syndrome (SIS); inflicted childhood neurotrauma; abusive head trauma (AHT); inflicted traumatic brain injury (inflicted TBI); and non-accidental head injury (NAHI). Reece, *supra* note 61. Indeed, the Committee

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and that the presence of retinal hemorrhages and subdural hematoma cannot conclusively prove that injury was inflicted.⁶⁹

Although it may be tempting to conclude simply that “science evolves,” and leave the inquiry there, the story is more complex; an object lesson in scientific overreaching and the challenge of correction.

A. Flawed Science

A number of forces coalesced to transform SBS from a certain diagnosis into its current state of flux. Most importantly, in the mid- to late-1990s,⁷⁰ medical research, including the SBS literature, became subject to a heightened level of scrutiny. The new “evidence-based medicine” standards required doctors to derive their research from methods that are scientific and statistically rigorous.⁷¹ The change triggered a review of the evidence supporting a number of areas of medicine,⁷² and included a comprehensive effort to examine the science underlying SBS.⁷³

The application of the evidence-based framework to the SBS literature resulted in a remarkable determination: the medical literature published prior to 1998 contained “inadequate scientific evidence to come to a firm conclusion on most aspects of causation, diagnosis, treatment, or any other matters pertaining to SBS.”⁷⁴ More specifically, “[s]erious data gaps, flaws of logic, [and] inconsistency of case definition” meant that “the commonly held opinion that the finding of SDH [subdural hematoma] and RH [retinal

on Child Abuse and Neglect of the American Academy of Pediatrics (AAP) recently recommended that “[p]ediatricians should use the term ‘abusive head trauma’ rather than a term that implies a single injury mechanism, such as shaken baby syndrome.” Cindy Christian et al., *Abusive Head Trauma in Infants and Children*, 123 PEDIATRICS 1409, 1411 (2009). Notwithstanding this proliferation of alternative diagnostic labels and the AAP’s newly articulated recommendation, both the medical and legal establishments continue to employ the terminology of SBS. For the sake of clarity, I will do so here as well.

69. See *infra* Part III.B.1.

70. “1998/1999 is regarded as the turning point in acceptance of the tenets and practice of EBM.” Mark Donohoe, *Evidence-Based Medicine and Shaken Baby Syndrome: Part I: Literature Review, 1966–1998*, 24 AM. J. FORENSIC MED. & PATHOLOGY 239, 239 (2003).

71. Testimony of Patrick Barnes in Transcript of Evidentiary Hearing (Day One) at 17–19, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. 2008) (No. 96 DF 555) [hereinafter Barnes testimony, Evidentiary Hearing (Day One)]. See Donohoe, *supra* note 70, at 239 (“In recent years, there has been a clear move toward basing medical practice and opinions on the best available medical and scientific evidence.”).

72. Donohoe, *supra* note 70, at 239.

73. *Id.* at 241.

74. *Id.*

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hemorrhage] in an infant was strong evidence of SBS was unsustainable.”⁷⁵

A logical fallacy of profound importance was uncovered by a close examination of the pre-1999 SBS literature: researchers had chosen subjects for study based on the presence of subdural hematomas and retinal hemorrhages and, with little or no investigation into other possible causes of these symptoms, simply concluded that the infants were shaken.⁷⁶ Scientists accordingly inferred that subdural hematomas and retinal hemorrhages must necessarily result from shaking.⁷⁷ Put differently, researchers “select[ed] cases by the presence of the very clinical findings and test results they [sought] to validate as diagnostic. Not surprisingly, such studies tend[ed] to find their own case selection criteria pathognomonic of SBS.”⁷⁸ The circularity of this logic is represented by the following equation: “SBS = SDH + RH [inclusion criteria], therefore SDH + RH = SBS [conclusion].”⁷⁹

Other studies purporting to support the validity of the SBS diagnosis relied on “confessions” to establish the mechanism of injury. Here, too, a number of problems undermined the validity of the research.⁸⁰ Putting aside momentarily the possibility that a suspected abuser would be less than candid with doctors and investigators,⁸¹ the classification of an account as a confession in these studies was highly problematic from a

75. *Id.* As defenders of the scientific research are quick to note, there are obvious “difficulties in performing experiments in this area,” since “[i]t is clearly unethical to intentionally shake infants to induce trauma.” *Id.* at 239.

76. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 28–29. “The major criticism of those who would indict and convict based on one or two talismanic findings of ‘shaken baby syndrome’ is that the justification for their opinions is based on nothing but circular reasoning.” Thomas L. Bohan, Letter to Editor, *Evaluating Evidence*, CHI. TRIBUNE, June 30, 2005.

77. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 28–29.

78. Donohoe, *supra* note 70, at 239. As Dr. Patrick Barnes, chief of pediatric neuroradiology at Stanford’s Children’s Hospital and a leading national expert in this area, has explained, “we as a group that wrote those papers assumed what we were concluding.” Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 27–28. According to Dr. Barnes’s testimony, he—along with many other scientists—“told a lie on child abuse based on old diagnostic criteria.” *Id.* at 70–71. He has since made every effort to correct his past mistakes. Interview with Thomas Bohan, President, Am. Acad. of Forensic Scis., in Peaks Island, Me. (June 11, 2008). Telephone Interview with John Plunkett, *supra* note 41.

79. Patrick D. Barnes, *Imaging of the Central Nervous System in Suspected or Alleged Nonaccidental Injury, Including the Mimics*, 18 TOPICS MAGNETIC RESONANCE IMAGING 53, 55 (2007). “The evidence for SBS appears analogous to an inverted pyramid, with a small database (most of it poor-quality original research, retrospective in nature, and without appropriate control groups) spreading to a broad body of somewhat divergent opinions.” Donohoe, *supra* note 70, at 239.

80. Jan E. Leestma, “Shaken Baby Syndrome”: Do Confessions by Alleged Perpetrators Validate the Concept?, 11 J. AM. PHYSICIANS & SURGEONS 14 (2006).

81. See *infra* notes 181–90 and accompanying text (discussing perpetrator accounts).

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methodological perspective: “where caretakers said that they shook the baby, it was never detailed how much they shook the baby, how long they shook the baby, and did the baby’s symptoms precede the shaking or did they follow the shaking.”⁸²

Once the edifice upon which SBS had been constructed cracked, researchers began looking beyond the child abuse literature to the expertise of neurosurgeons, biomechanical engineers,⁸³ and pathologists.⁸⁴ Knowledge gained from these disciplines further eroded confidence in the existence of a pathognomonic relationship between shaking and the SBS triad.⁸⁵

Around the same time, magnetic resonance imaging (MRI) revolutionized the field of radiology and significantly altered the diagnostic universe.⁸⁶ Compared to its precursor, computed tomography (CT), MRI enabled a far more detailed assessment of the “pattern, extent, and timing” of central nervous system injuries.⁸⁷ New radiological findings challenged what had become akin to scientific gospel,⁸⁸ revealing the presence of triad symptoms in the “mimics” of abuse: accidental injury and medical disorders manifesting as SBS.⁸⁹ And as technology and scientific methodology advanced, researchers questioning the basis for SBS reached a critical mass.⁹⁰

82. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 31. One expert has remarked that it is not surprising that a caregiver would shake a child found unconscious, both because this response is almost instinctual and because the medical establishment once instructed that “if you have an unresponsive child, one of the first things you do is you jiggle or shake them and see if they will respond.” *Id.* See also *infra* notes 181–90 and accompanying text [same as above]. Cf. *Hess v. Tilton*, No. CIV S-07-0909WBSEFBP, 2009 WL 577661 (E.D. Cal. Mar. 5, 2009) (defendant “admitted that he shook [the baby] but insisted it was only in an attempt to clear her throat because she was choking on her own vomit”).

83. Biomechanical research has practical application to “child safety, car seats, [and] playground equipment. . . .” Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 25.

84. *Id.* at 24–25. Although “much of [this] literature was available before 1998, [it] was not widely read or applied by the child protection teams . . . and, particularly, the forensic pediatricians . . .” *Id.* at 25.

85. *Id.* at 24–25.

86. *Id.* at 26, 115.

87. Patrick D. Barnes, *Ethical Issues in Imaging Nonaccidental Injury: Child Abuse*, 13 TOPICS MAGNETIC RESONANCE IMAGING 85, 89 (2002); see also Marguerite M. Caré, *Neuroradiology, in ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN: A MEDICAL, LEGAL, AND FORENSIC REFERENCE* #, 89 (Lori Frasier et al. eds., 2006).

88. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 26.

89. *Id.* at 23, 52–53. See *infra* notes 132–36 and accompanying text (discussing SBS mimics).

90. Interview with Thomas Bohan, *supra* note 78. For an interesting discussion of the “critical role that groups play in social epidemics,” see *Power of Context (Part Two)*, in MALCOLM GLADWELL, *THE TIPPING POINT: HOW LITTLE THINGS CAN MAKE A BIG DIFFERENCE* 169, 171 (Little, Brown and Co. 2000).

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This momentum was catalyzed by the high-profile prosecution of British au pair Louise Woodward, which in 1997 brought shaken baby syndrome into the international spotlight.⁹¹ The case was widely perceived as “one of the more intriguing legal dramas of the age—one that [left] unresolved a mystery of sickening fascination to parents everywhere.”⁹² In its wake, an already divided scientific community became even more polarized. Physicians felt “compelled to speak out regarding the scientific evidence as portrayed in the trial of Louise Woodward,” contending that “media publicity surrounding the case has led to considerable sentiment that she was convicted despite allegedly irrefutable scientific evidence presented by the defense that the infant’s injuries had occurred days to weeks earlier.”⁹³ And critics of the SBS diagnosis were galvanized by a legal and symbolic victory that commanded the world’s attention.

In response to these developments, an uneasy equilibrium has been reached. Once considered a “fringe” group, scientists challenging the SBS dogma have emerged as a significant force in terms of numbers as well as influence. Meanwhile, rather than abandon it altogether, defenders of the

91. *Commonwealth v. Woodward*, No. CRIM. 97-0433, 1997 WL 694119, at *1 (Mass. Sup. Ct. Nov. 10, 1997). The defendant called 911 to report that she could not rouse eight-month-old Matthew Eappen from his nap. Debra Rosenberg & Evan Thomas, ‘I Didn’t Do Anything’, *NEWSWEEK*, Nov. 10, 1997, available at <http://www.newsweek.com/id/97361>. Doctors found massive intracranial bleeding, brain swelling, and a retinal hemorrhage, and Matthew later died. *Nanny Murder Trial—Jury Still Out*, BBC NEWS, Oct. 30, 1997, available at http://news.bbc.co.uk/1/hi/programmes/from_our_own_correspondent/16726.stm. The prosecution, as is typical in SBS cases, rested almost entirely on medical evidence. Experts testified that “there was no doubt . . . that this infant was a victim of shaken baby syndrome,” and that this was “a classic picture of acute shaken baby injury.” *Id.*

The defense challenged the science more aggressively—and far more publicly—than had ever been done before. See *id.* (describing “clash of the medical men” in which “[b]oth teams produced ‘the world’s leading experts’ to make their own case”). Woodward was represented by Barry Scheck, one of the nation’s preeminent defense attorneys, whose advocacy proved the difference that resources can make. See Rosenberg & Thomas, *supra* (“Scheck and his team hired medical experts (at the cost of thousands of dollars a day) who testified that Matthew’s skull fracture had occurred about three weeks before he died, and that the fatal bleeding could have been unleashed by just a slight jar.”). The defense presented a number of experts to testify to an alternative theory of Matthew’s death. According to this testimony, the fatal hemorrhage was caused by a “re-bleed” of a chronic brain clot resulting from an undetected injury. *Woodward*, 1997 WL 694119, at *1. See *infra* note 194 (citing supporting re-bleed theory). The trial “roil[ed] two nations.” Rosenberg & Thomas, *supra*. After a jury convicted the defendant of murder, the trial judge reduced the verdict to involuntary manslaughter and sentenced Woodward to time already served. *Commonwealth v. Woodward*, 694 N.E.2d 1277, 1281 (Mass. 1998). In his order, the judge articulated one rational view of the evidence which would constitute manslaughter: the baby had a chronic blood clot which re-bled upon “rough” handling by Woodward. *Id.* at 1287.

92. Rosenberg & Thomas, *supra* note 91.

93. David L. Chadwick et al., Letter to the Editor, *Shaken Baby Syndrome—A Forensic Pediatric Response*, 101 *PEDIATRICS* 321, 321 (1998).

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validity of the diagnosis have adapted it in subtle but important ways: SBS has been reincarnated to reflect a shifted consensus.⁹⁴

B. Shifted Consensus

Since the mid-1990s, the science surrounding SBS has undergone a striking transformation. With little attention outside of the medical community, universally held tenets have been undermined, leading a segment of the scientific establishment—including some formerly prominent supporters of its validity—to perceive the diagnosis as illegitimate. Others, equally distinguished in their respective fields, have responded to the new research by defending SBS against attack.⁹⁵ Thus, despite the progression of scientific discourse, the current debate about shaken baby syndrome is remarkably polarized.⁹⁶ Scientists on each side of the controversy espouse their respective views with a passion and certainty matched in intensity by that of their opponents.⁹⁷

This polarization, and the bitterness that accompanies it, can tend to obscure a significant area of consensus that has developed around the invalidity of previously accepted dogma. Doctors who defend the legitimacy of SBS and dismiss many of its critics' attacks are willing to concede that the science has evolved—and that even mainstream thinking has changed in a number of areas. The testimony of prosecution experts marks this movement.⁹⁸

The movement is subtle, but undeniable. Its significance may depend upon the context in which it is being evaluated. From the perspective of "pure" science, the similarities between the two factions may be overshadowed by their unresolved differences;⁹⁹ but in the criminal justice

94. Defenders of the new SBS adhere to the view that the cluster of triad symptoms, while not *pathognomonic* of abuse, are *generally indicative* of violent shaking and/or impact. See *infra* notes 107–09 and accompanying text.

95. Defenders of the validity of the diagnosis fall along a spectrum. For instance, without rejecting the construct in its entirety, many physicians have revised their thinking about the original or "strong" version of SBS—i.e., the syndrome defined by a triad of symptoms understood to be *pathognomonic* of shaking. See *infra* Part III.B.1.

96. See *infra* notes 109, 113, 123, 128–29 and accompanying text.

97. *Id.*

98. See, e.g., Testimony of William Perloff in Transcript of Evidentiary Hearing (Day Four) at 11–12, *State v. Edmunds*, 746 N.W.2d 590 (2008) (No. 96 CF 555); Testimony of Betty Spivak in Transcript of Evidentiary Hearing (Day Three) at 12–14, *State v. Edmunds*, 746 N.W.2d 590 (2008) (No. 96 CF 555) [hereinafter Spivak testimony, Evidentiary Hearing (Day Three)].

99. Evaluating this claim is complicated, given that the notion of "pure science" in the domain of SBS may well be a fiction.

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setting, the new common ground should be of critical importance. A brief overview of what has become uncontroversial reveals why.

1. *The Myth of Pathognomonny*

An emerging body of research has undermined the scientific basis for defining the triad of SBS symptoms as exclusively diagnostic of abuse.¹⁰⁰ No longer are physicians willing to state with certainty that the constellation of symptoms that once characterized SBS individually¹⁰¹ and collectively¹⁰² must in every case indicate that a child was abused.¹⁰³ In particular, as scientific study has generated new explanations for the presence of subdural hematomas¹⁰⁴ and retinal hemorrhages,¹⁰⁵ doctors have become increasingly reluctant to use the word pathognomonic when discussing these symptoms.¹⁰⁶ While many disagree vehemently with the contention that shaking alone cannot possibly cause the diagnostic triad,¹⁰⁷ they have conceded that the triad is not *necessarily* induced by shaking,

100. See, e.g., J. Plunkett and J.F. Geddes, Letter, *The Evidence Base for Shaken Baby Syndrome*, 328 BRIT. MED. J. 719, 720 (2004) (urging “reconsider[ation of] the diagnostic criteria, if not the existence, of shaken baby syndrome”).

101. In cases, the presence of subdural hematoma or retinal hemorrhage alone has provided the basis for an SBS diagnosis. *Id.* at 719. See *infra* note 280 and accompanying text (describing prosecutions of this kind).

102. See Clinical Statement of American Academy of Ophthalmology, http://one.aao.org/CE/PracticeGuidelines/ClinicalStatements_Content.aspx?cid=c379ec3e-8251-48e6-a88e-fb6f37954b14 (last visited July 20, 2009).

103. See *supra* notes 60–64 and accompanying text.

104. See, e.g., Marta C. Cohen & Irene Scheimberg, *Evidence of Occurrence of Intradural and Subdural Hemorrhage in the Perinatal and Neonatal Period in the Context of Hypoxic Ischemic Encephalopathy*, 12 PEDIATRIC DEVELOPMENTAL PATHOLOGY 169 (2009); Julie Mack et al., *Anatomy and Development of the Meninges: Implications for Subdural Collections and CSF Circulation*, 39 PEDIATRIC RADIOLOGY 200 (2009) (on file with author); Eva Lai Wah Fung et al., *Unexplained Subdural Hematoma in Young Children: Is it Always Child Abuse?*, 44 PEDIATRICS INT’L 37 (2002); V.J. Rooks et al., *Prevalence and Evolution of Intracranial Hemorrhage in Asymptomatic Term Infants*, 29 AM. J. NEURORADIOLOGY 1082 (2008).

105. See, e.g., P.E. Lantz et al., *Perimacular Retinal Folds from Childhood Head Trauma*, 328 BRIT. MED. J. 754 (2004); Gregg T. Leuder et al., *Perimacular Retinal Folds Simulating Nonaccidental Injury in an Infant*, 124 ARCHIVES OPHTHALMOLOGY 1782 (2006).

106. There has been widespread acknowledgment that what one researcher has called “the proposed pathognomonic association between unexplained subdural hematoma/retinal hemorrhages and child abuse” may be suspect. Fung et al., *supra* note 104, at 37 (adopting a cross-cultural perspective and concluding that the diagnosis may be a “self-fulfilling prophecy”). This concession has been articulated by even those physicians who maintain the validity of the diagnosis. Interview with Lawrence Ricci, Dir., Spurwink Child Abuse Program, in Portland, Me. (June 12, 2008); Telephone Interview with Stephen Boos, *supra* note 66. See also C. Smith & J. Bell, *Shaken Baby Syndrome: Evidence and Experts*, 50 DEVELOPMENTAL MED. & CHILD NEUROLOGY 6, 7 (2008) (arguing that “trauma remains the most likely cause of SDH [subdural hemorrhage] in infancy” while “stress[ing] that the triad is not pathognomonic of inflicted injury”).

107. See *infra* Part III.B.3.

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and that a differential diagnosis must be considered.¹⁰⁸ This represents a dramatic evolution in mainstream scientific thinking.

Critics of the new research argue that shaking is still the most likely explanation for retinal hemorrhaging and subdural hematoma.¹⁰⁹ Nevertheless, given that the diagnostic paradigm rests fully on the triad, the move away from pathognomony inevitably reframes ongoing debate.

2. *Lucid Intervals*

In the past, defendants prosecuted for SBS were identified by the science—that is, by the certainty of doctors that the perpetrator of abuse was necessarily the person with the infant immediately prior to the loss of consciousness. However, studies have since shown that children suffering fatal head injury may be lucid for more than seventy-two hours before death.¹¹⁰ Because the prospect of a lucid interval lessens the ability to pinpoint when an injury was inflicted, this research dramatically alters the forensic landscape. Without other evidence, the identity of a perpetrator—assuming a crime has occurred—simply cannot be established.¹¹¹

Similarly, whereas before, doctors effectively foreclosed the possibility that prior accidental injury caused an infant's later symptoms, lucid interval studies support the notion of a lag time.¹¹²

Those who dispute the importance of this research note that the concept of lucidity is ambiguous and argue that, even in an interval classified as lucid, an infant suffering from fatal head trauma would show signs of severe neurological damage.¹¹³ At least one documented case—where a hospitalized child was observed by medical personnel in a “clingy, but

108. In SBS cases, the differential diagnosis is a list of possible causes of the infant's symptoms. It results from a methodology that seeks to eliminate those factors that cannot have contributed to the injuries. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 12, 32. For further discussion of the differential diagnosis, see *infra* notes 134–36 and accompanying text.

109. This perspective was articulated repeatedly in my conversations with physicians. It is also represented in the scientific literature. See, e.g., David L. Chadwick et al., *Annual Risk of Death Resulting from Short Falls Among Young Children: Less than 1 in 1 Million*, 121 PEDIATRICS 1213 (2008).

110. See, e.g., M.G.F. Gilliland, *Interval Duration Between Injury and Severe Symptoms in Nonaccidental Head Trauma in Infants and Young Children*, 43 J. FORENSIC SCI. 723 (1998); Kristy B. Arbogast et al., In Reply to Letter to Editor, *Initial Neurologic Presentation in Young Children Sustaining Inflicted and Unintentional Fatal Head Injuries*, 116 PEDIATRICS 1608 (2005).

111. See *infra* note 250 (noting, among others, cases where identity is in dispute).

112. See *supra* note 110.

113. Interview with Lawrence Ricci, *supra* note 106; Spivak testimony, Evidentiary Hearing (Day Three), *supra* note 98, at 94–102.

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perfectly responsive” state for sixteen hours before her death¹¹⁴—has proven otherwise.¹¹⁵

But here, again, the emerging consensus dwarfs the continuing disagreement.¹¹⁶ A period of time can exist where a child is impaired but functioning,¹¹⁷ making the lucid interval “a distinct discomforting but real possibility.”¹¹⁸ In the past, caregiver accounts of seemingly unprecipitated neurological crises were dismissed or even deemed inculpatory.¹¹⁹ These accounts must now be evaluated with the possibility of a lucid interval in mind.

3. *Removing the Shaking from the Syndrome*

New debate has emerged regarding whether shaking can generate the force levels sufficient to cause the injuries associated with SBS. Those who believe it cannot point to a number of biomechanical studies, as well as research using animal and computer models.¹²⁰ Many of these scientists assume *arguendo* that rotational acceleration-deceleration forces can, in theory, cause retinal hemorrhage and subdural hematoma, but contend that shaking an infant with sufficient force to do so would necessarily damage

114. Testimony of Robert Huntington in Transcript of Evidentiary Hearing (Day Two) at 36, *State v. Edmunds*, 746 N.W.2d 590 (2008) (No. 96 CF 555) [hereinafter Huntington testimony, Evidentiary Hearing (Day Two)].

115. See Robert Huntington, Letter, *Symptoms Following Head Injury*, 23 AM. J. FORENSIC MED. & PATHOLOGY 105 (2002) (describing case study in which infant was observed by hospital personnel in prolonged lucid state before dying from injuries associated with SBS). This case (“Hernandez”) had a transformative effect on Dr. Huntington, the pathologist who performed the autopsy in *Edmunds*. At trial, Dr. Huntington testified that it was “highly probable” that Natalie had been injured within two hours of being seen by medical personnel. Huntington testimony, Evidentiary Hearing (Day Two), *supra* note 114, at 33. Based on his subsequent involvement with the Hernandez case, Dr. Huntington testified on behalf of Edmunds at her 2007 post-conviction evidentiary hearing that he had “changed [his] opinion about whether there could be a significant lucid interval after injury[.]” *Id.* at 34. See *infra* Part IV.E.1. Although Hernandez is factually *sui generis*, “everybody agrees that the single incident, the single validated case can falsify a theory. That’s what’s significant about them.” Attorney for the Defense in Transcript of Oral Argument (Day 5) at 132–33, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. Mar. 8, 2007) (No. 96 CF 555).

116. There seems to be general agreement in the medical community that, in nonlethal cases, where a child typically presents as lucid, the science can even less readily identify a perpetrator. Interview with Ricci, *supra* note 106; Telephone Interview with Stephen Boos, *supra* note 66.

117. Experts may debate whether the exhibiting signs were so severe that medical professionals would have been aware of a problem, but this does not equate to what a nonmedical person would necessarily conclude—which, for purposes of evaluating a caregiver history, would seem to be the relevant inquiry.

118. Huntington testimony, Evidentiary Hearing (Day Two), *supra* note 114, at 44.

119. See *infra* notes 80–82 and accompanying text. See also Part IV.A.2.

120. See, e.g., A.C. Duhaime et al., *The Shaken Baby Syndrome: A Clinical, Pathological, and Biomechanical Study*, 66 J. NEUROSURGERY 409 (1987); A.K. Ommaya et al., *Biomechanics and Neuropathology of Adult and Paediatric Head Injury*, 16 BRIT. J. NEUROSURGERY 220 (2002).

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the neck and cervical spinal cord or column. Since most infants diagnosed with SBS do not present this type of injury,¹²¹ they could not have been simply shaken.¹²²

This perspective remains subject to considerable criticism within the medical establishment.¹²³ But even those who vehemently dispute the conclusion that shaking alone cannot cause the triad have revised their thinking. No longer is shaking advanced as an exclusive etiology.¹²⁴ Instead, the current position of this group of physicians with respect to nonnatural forces (i.e., intentional or accidental trauma) is that either shaking *or* impact may cause the classic triad.¹²⁵ More important is the widespread recognition that the two possible mechanisms cannot be clinically differentiated. Thus, the most committed defenders of the validity of the SBS diagnosis now allow that impact cannot be eliminated as a potential causal mechanism.

Once this fact is acknowledged, the question of how much force is required to generate the types of injury associated with SBS becomes critical to whether trauma was inflicted, accidental, or undeterminable.

121. "As forensic pathologists are keenly aware, neck injuries in a 'shaken' child are a rarity, not a commonality." Kimberley Molina, *Neck Injuries and Shaken Baby Syndrome*, 30 AM. J. FORENSIC MED. & PATHOLOGY 89 (2009) (citing data presented at Annual Meeting of the National Association of Medical Examiners indicating 0% incidence of neck injuries in seventy-nine potential "shaking" cases).

122. See, e.g., Faris A. Bandak, *Shaken Baby Syndrome: A Biomechanics Analysis of Injury Mechanisms*, 151 FORENSIC SCI. INT'L 71 (2005).

123. Among those who believe that shaking *can* cause the constellation of SBS injuries, some are willing to concede that this has not been scientifically proven. These physicians posit that the absence of proof is a reflection of poor modeling, rather than anatomical impossibility. They also note that researchers are obviously unable to shake live babies (and ethical considerations prevent this kind of experiment on animals that would be useful for comparison). According to those who adhere to the notion that shaking may result in the diagnostic triad, these realities make it extremely difficult to prove the causal mechanism involved in SBS. Telephone Interview with Stephen Boos, *supra* note 66; Interview with Lawrence Ricci, *supra* note 106.

Along these same lines, in the past, doctors were certain, not only that shaking was the mechanism at issue, but also that the shaking necessary to cause the triad of symptoms associated with SBS was of such an extremely forceful nature that the causal act could not be anything other than abuse. To illustrate the point, doctors compared the hypothesized forces at issue to known causes of subdural hematoma and retinal hemorrhage—i.e., falls off of multi-story buildings and car crashes—and they modeled this violent shaking with baby dolls. See *supra* notes 19–20 and accompanying text. Today, confronting the absence of a solid scientific basis for these claims, and in recognition of the logic that such extreme force might be expected to cause neck and cervical cord injury, the conventional wisdom regarding degree of force has been disavowed. Telephone Interview with Stephen Boos, *supra* note 66; Interview with Lawrence Ricci, *supra* note 106. Disagreement continues, however, regarding whether this type of injury is always clinically discernable.

124. See *supra* notes 60–64 and accompanying text (describing original formulation of SBS diagnosis).

125. Telephone Interview with Stephen Boos, *supra* note 66; Interview with Lawrence Ricci, *supra* note 106. See also Duhaime, *supra* note 120.

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The latest thinking about force thresholds complicates this inquiry. New research shows that relatively short-distance falls may cause fatal head injury that looks much like the injury previously diagnosed as SBS.¹²⁶ Moreover, these signs and symptoms may not appear immediately.¹²⁷

While the “short-fall” literature continues to be a source of debate¹²⁸ and its scientific significance minimized by some,¹²⁹ the potential impact of these findings on criminal prosecutions is enormous.¹³⁰ Where doctors would previously have been certain that an infant was shaken, in many cases¹³¹ a fall must now be entertained as an explanation for injuries.¹³² Once the threshold of force sufficient to cause the injuries at issue has been cast into doubt, scientific identification of a causal mechanism that is

126. “The injury may be associated with bilateral retinal hemorrhage, and an associated subdural hematoma. . . .” John Plunkett, *Fatal Pediatric Head Injuries Caused by Short-Distance Falls*, 22 AM. J. FORENSIC MED. & PATHOLOGY 1, 10 (2001). See generally Scott Denton, *Delayed Sudden Death in an Infant Following an Accidental Fall: A Report with Review in the Literature*, 24 AM. J. FORENSIC MED. & PATHOLOGY 239 (2003).

127. *Id.* See *infra* Part III.B.2.

128. See, e.g., Robert M. Reece, Letter, *The Evidence Base for Shaken Baby Syndrome: Response to Editorial from 106 Doctors*, 328 BRIT. MED. J. 1316 (2004).

129. See, e.g., Testimony of Jeffrey Jentzen, in Transcript of Evidentiary Hearing (Day Three) at 30–35, *State v. Edmunds*, 746 N.W.2d 590 (2008) (No. 96 CF 555). Other physicians, even those who generally testify on behalf of the prosecution in SBS cases, have conceded the importance of the short-falls findings. See, e.g., Testimony of Alex Levin in Transcript of Evidentiary Hearing (Day Four) at 133, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. 2008) (No. 96 CF 555) (characterizing this research as “valuable addition to the literature”).

130. The implications of this research extend beyond traditional SBS prosecutions. For instance, in Texas, one death row inmate, Cathy Lynn Henderson, was recently granted a stay of execution and a hearing on her habeas motion based on newly available scientific evidence regarding the effects of short falls on pediatric head trauma. *Ex parte Henderson*, 246 S.W.3d 690 (Tex. Crim. App. 2007). At her trial in 1995, Henderson claimed that she had accidentally dropped the infant from her arms—a contention effectively rebutted by the testimony of prosecution experts, who unanimously concluded that the infant’s extensive brain injuries must necessarily have been caused by intentionally slamming of the head against a hard surface. *Id.* at 691. The certainty attending this conclusion has since been undermined by the short-fall literature, as evidenced by the affidavits and reports submitted by the defendant in support of her motion for habeas relief. *Id.* Most notably, the medical examiner who testified for the prosecution “in essence, recant[ed] his trial-time conclusive opinion” as a result of the “new scientific information” not available when Henderson was convicted of capital murder. *Id.* at 692. As this Article goes to print, the trial court has not yet ruled on an evidentiary hearing held earlier this year.

131. To be clear, falls are not the only alternative explanation for the SBS triad. See *infra* notes 134–36 and accompanying text (discussing natural causes). Depending on the case—in particular, the available physical/forensic evidence (or lack thereof) and the caregiver’s account—a fall may be more or less likely than other possible causes of injury.

132. Infants’ heads may encounter impact in a variety of ways: babies fall from high chairs, beds and stairs; babies are accidentally dropped. “A history by the caretaker that the child may have fallen cannot be dismissed.” Plunkett, *supra* note 126, at 10. Given the frequency with which caregivers offer a fall as explanation for the child’s injuries, see *infra* note 181, this scientific development has real criminal justice significance.

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abusive¹³³ becomes problematic. Put differently, the medical testimony can no longer do the work of establishing *mens rea*.

Just as researchers have identified the possibility of accidental trauma as a cause of the SBS triad, so, too, has increasing attention been given to of a number of nontraumatic causes of symptoms previously assumed to be pathognomonic of shaking.¹³⁴ A “number of medical disorders documented in the medical peer-reviewed literature . . . can mimic [abusive head trauma],” including congenital malformations, metabolic disorders, hematological diseases, infectious diseases and autoimmune conditions.¹³⁵ In sum, depending upon the clinical picture presented, the differential diagnosis for symptoms previously associated exclusively with SBS now contemplates a wide range of nontraumatic possibilities: medical or surgical interventions; prenatal, perinatal and pregnancy-related conditions; birth effects; infections; diseases; disorders; malformations; post-vaccinal conditions; re-bleeds; and hypoxia (lack of oxygen to the brain).¹³⁶

Notwithstanding these rather seismic shifts in medical thinking, the criminal justice system has—with only rare and recent exception—been unyielding to new thinking about a diagnosis that proves a crime.

IV. SBS AND THE LAW

Given the scientific developments described, we may surmise that a sizeable portion of the universe of defendants convicted of SBS-based crimes is, in all likelihood, factually innocent. Even more certainly, a far greater number of defendants among this group were wrongfully convicted. The distinction is an important one:

The expression “wrongful conviction” is not a legal term of art and it has no settled meaning. Plainly the expression includes the conviction of those who are innocent of the crime of which they have been convicted. But in ordinary parlance the expression would, I think, be

133. The use of “abusive” in this context is meant to convey a mental state beyond negligence, which accords with the vast majority of SBS-based criminal prosecutions. *See infra* note 248 (elaborating on requisite *mens rea*).

134. *See supra* note 108 (defining “differential diagnosis”).

135. Andrew P. Sirotnak, *Medical Disorders that Mimic Abusive Head Trauma*, in *ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN: A MEDICAL, LEGAL, AND FORENSIC REFERENCE* 191 (Lori Frasier et al. eds., 2006). *See also* Barnes, *supra* note 79.

136. *See generally* K. Hymel et al., *Intracranial Hemorrhage and Rebleeding in Suspected Victims of Abusive Head Trauma: Addressing the Forensic Controversies*, 7 *CHILD MALTREATMENT* 329 (2002); Barnes, *supra* note 87; *see also supra* notes 104–05.

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extended to those who, whether guilty or not, should clearly not have been convicted at their trials In cases of this kind,¹³⁷ it may, or more often may not, be possible to say that a defendant is innocent, but it is possible to say that he has been wrongly convicted. The common factor in such cases is that something has gone seriously wrong in the investigation of the offence or the conduct of the trial, resulting in the conviction of someone who should not have been convicted.¹³⁸

In SBS cases, identifying the factually innocent is complicated by two related propositions. First, no crime whatsoever may have occurred, thus eliminating the opportunity to establish someone else's culpability.¹³⁹ Second, at least to date, science has not definitively established an alternative explanation for the injuries associated with SBS.¹⁴⁰ What this means is that a significant number of people convicted in triad-only prosecutions¹⁴¹ are likely innocent of wrongdoing, but others are not, and we have no way of differentiating between these groups.¹⁴² Accordingly, we may rightly be troubled by the convictions of those whose factual innocence is unproven.

The criminal justice implications of all of this are staggering.¹⁴³ To put the scope of the problem in a more familiar framework, it is helpful to

137. Cases in which "flawed expert evidence was relied on to secure conviction" are specifically referenced. *Infra* note 138.

138. This passage is taken from a speech of Lord Bingham, the senior law lord in the United Kingdom until his retirement, in *R (on the application of Mullen) v. Secretary of State for the Home Department* [2005] 1 AC 1, 4, cited in Stephanie Roberts & Lynne Weathered, *Assisting the Factually Innocent: The Contradictions and Compatibility of Innocence Projects and the Criminal Cases Review Commission*, 29 OXFORD J. LEGAL STUD. 43, 50 (2009).

139. "Proving that someone else committed the crime is by far the most common method of achieving an exoneration, but it is unavailable if there was no crime at all." Samuel R. Gross, *Convicting the Innocent*, 4 ANN. REV. L. & SOC. SCI. 173, 183 (2008).

140. See *infra* notes 233–45 and accompanying text (discussing the challenges associated with the differential diagnosis).

141. See *supra* note 58 (defining term). For the moment, I put aside cases in which a suspect's seemingly incriminatory account was used—in retrospect, incorrectly—to corroborate the prosecutor's case. See *infra* notes 183–90 and accompanying text.

142. My thanks to Robert Mosteller for helping me to arrive at this formulation. E-mail from Robert Mosteller, Harry R. Chadwick Sr. Professor of Law, Duke University, to Deborah Tuerkheimer, Professor, University of Maine School of Law (Aug. 29, 2008, 15:46 EST) (on file with author).

143. In the estimation of one forensic medical expert, SBS cases may be divided into four groups. One includes those where injury is clearly inflicted, in all likelihood, by impact. Although, in this group, the causal mechanism may not be shaking, medical evidence apart from the triad indicates to a reasonable degree of scientific certainty that the baby was abused. In these cases, a finding of guilt seems just. The three remaining groups of cases involve evidence that, from a criminal justice stance, tends to negate proof beyond a reasonable doubt of a defendant's guilt: evidence of natural disease, the

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consider the number of known exonerations in the United States over the past thirty years. From 1989 through 2007, there were 210 DNA exonerations, mostly for rape.¹⁴⁴ It is reasonable to suspect that this number of SBS-based convictions after trial occurred in the past year alone.¹⁴⁵ Additional (non-DNA) exonerations include those of 111 inmates on death row, 135 other individuals, and perhaps another 200 or so defendants whose convictions were overturned based on a “mass” scandal implicating widespread systemic corruption.¹⁴⁶ Unlike SBS cases, none of these exonerations involve a set of paradigmatic facts later determined to be a faulty basis for prosecution.¹⁴⁷

Despite the large numbers of potentially impacted cases—or perhaps, because of them—our criminal justice system has yet to respond to new scientific realities.¹⁴⁸ Its failure to do so stands in marked contrast to other nations’ recognition of the problematic nature of pure-triad prosecutions. The emphatic institutional responses of the United Kingdom¹⁴⁹ and

presence of chronic hematomas, and those in which no likely mechanism presents itself. Telephone Interview with John Plunkett, *supra* note 41.

144. Gross, *supra* note 139, at 175. Of course, DNA has uncovered only a fraction of the cases in which an innocent person was convicted. For a comprehensive examination of what is known—and all that we have yet to learn—about false convictions over the past thirty years, see Gross, *supra* note 139.

145. See *supra* note 56 and accompanying text. To be clear, I do not mean to suggest that every one of these post-trial convictions would, upon review, be found wrongful. See *supra* notes 58, 143 (refining subset of problematic cases). That said, a fair accounting of the number of defendants whose convictions have been undermined by scientific developments must also contemplate the possibility that some defendants who pleaded guilty before trial were innocent. See *supra* note 57; Gross, *supra* note 139, at 180–81 (generally discussing the difficulty of assessing how many innocent defendants plead guilty). Moreover, any inquiry aimed at quantitative measure should also acknowledge that triad-only prosecutions continue to this day; therefore, a true reckoning of the magnitude of injustice implicates a somewhat prospective outlook.

146. Gross, *supra* note 139, at 175–76.

147. As Sam Gross suggested to me, arson cases may provide the closest analogy, albeit an imperfect one, to the problem that I am describing. Telephone Interview with Samuel Gross, *supra* note 50. In 1992, the National Fire Protection Association “issued new guidelines that for the first time applied scientific principles to the analysis of the remains of suspicious fires, and revealed that the expert evidence of arson in [one death row inmate’s] case, and many others, had no scientific basis.” Gross, *supra* note 139, at 183.

148. As a general proposition, the U.S. criminal justice system—in contrast to those of many other nations—does not respond to extra-legal developments in a monolithic manner. Our system is atomized by its federalist, multi-state nature and by the multiplicity of actors involved in decision making throughout the criminal process. To explicate how scientific developments around SBS have penetrated the justice system, is, therefore, a formidable challenge. This difficulty is compounded by the extent to which SBS prosecutions, as a phenomenon of increasing importance, have gone largely unnoticed and data related to them correspondingly uncollected. Despite this, a procedural analysis of the various stages at which legal standards guide the exercise of discretion follows. It provides a holistic perspective on a system that has not widely absorbed new scientific realities.

149. In 2005–2006, the Attorney General, Lord Goldsmith, conducted a seven-month review of eighty-eight SBS cases, including guilty verdicts and pleas. (SBS convictions are significantly less commonplace in the United Kingdom than in the States.) Lord Goldsmith’s investigation was triggered

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Canada¹⁵⁰ are particularly instructive. Just as our criminal justice system has seemed to operate within a time bubble, largely untouched by scientific evolution, so, too, it remains insulated from unmistakable signs

by a 2005 Court of Appeal decision, now the governing case law, which concluded that “[i]n cases where the triad alone is present . . . the triad alone ‘cannot automatically or necessarily’ lead to a conclusion that the infant has been shaken.” THE RT HON THE LORD GOLDSMITH QC, THE REVIEW OF INFANT DEATH CASES: ADDENDUM TO REPORT SHAKEN BABY SYNDROME at 9–10 (2006). The Attorney General’s review methodology is vulnerable to criticism, particularly because among the evidence considered “to support the finding of SBS” was a defendant’s “[a]dmissions to shaking” and the presence of chronic subdural hematomas, *id.* at 12, each of which may be of limited corroborative value, *see infra* notes 104, 183–90 and accompanying text. This may explain why only three of the cases reviewed—a not insubstantial false conviction rate of 3.4%, but fewer than what many had expected—were identified as “giving rise to concern” and referred to the Criminal Court of Appeal. Goldsmith, *supra*, at 14. Irrespective of methodological shortcomings, however, Lord Goldsmith’s systemic review and the Court of Appeal decision that preceded it have appreciably altered the course of SBS prosecutions. As one commentator has suggested, “in [the] future there will be demands for each case to be assessed individually, on the evidence available, rather than on a formula which has now been proved to have weaknesses.” Sam Lister, *Q&A: Shaken Baby Syndrome*, TIMES ONLINE, Feb. 14, 2006, www.timesonline.co.uk/tol/news/uk/article546383.ece.

150. On April 25, 2007, the Province of Ontario established an inquiry into pediatric forensic pathology and appointed Justice Stephen Goudge of the Court of Appeal its Commissioner. Seventeen months and \$8.3 million later, Justice Goudge issued a 1000 page report which told what he called a “tragic story of pediatric forensic pathology in Ontario from 1981 to 2001. . . .” COMMISSIONER’S STATEMENT ON RELEASE OF THE REPORT, Oct. 1, 2008. Many of the Commission’s findings related specifically to the mistakes of one particular forensic pathologist and a failed oversight mechanism. But apart from the work of any individual, the report expressed deep concerns about the legitimacy of triad-based SBS prosecutions, concluding that in this set of cases, “a further review is warranted as part of restoring public confidence.” *Id.* See Goudge, *supra* note 59, at 531 (“[O]ur systemic examination has identified this particular area of forensic pathology as one where change has raised the real possibility of past error.”). In light of his doubts regarding “convictions based on the pure ‘triad,’ where no other pathology evidence is identified, and possibly in other SBS cases,” *id.* at 528, Justice Goudge recommended that a review be conducted with the objective of “identify[ing] those cases in which the pathology opinion can be said to be unreasonable in light of the understandings of today and in which the pathologists’ opinions were sufficiently important to the case to raise significant concerns that the convictions were potentially wrongful,” *id.* at 531. Because many of the convicted parties are now claiming that their pleas were “induced by various factors, including the serious consequences of potentially being convicted of murder charges and the acknowledged difficulties in challenging [the state’s forensic pathologist’s] opinions,” the report emphasized that “cases should not be excluded from review only because an accused pleaded guilty.” *Id.* at 532–33. Justice Goudge’s findings and conclusions are detailed extensively in his full report, *supra* note 59.

Upon issuance of the Goudge Commission Report, the Ontario coroner’s office quickly identified 220 cases where a determination was made that an infant died after being shaken. Antonella Artuso, *Shaken Baby Doubts Surface*, OTTAWA SUN, Oct. 2, 2008, at 7. Under the auspices of the Attorney General, 142 of these cases are being reviewed by a team which includes the province’s former associate chief justice, its chief forensic pathologist, a regional supervising coroner, a senior defense counsel, and a senior Crown attorney. Theresa Boyle, *Team Selected to Probe 142 Shaken Baby Cases*, THE TORONTO STAR, Dec. 2, 2008, *available at* thestar.com. On November 6, 2008, Anna Sokolnyuk was the first person to have a case dismissed based on the Attorney General’s review. She had been charged with murder for the death of her three-month-old daughter. *Mom of Dead Baby Walks Free After Charges Against Her Withdrawn in Court*, TORONTO CITY NEWS, Nov. 6, 2008, http://www.citynews.ca/news/news_28894.aspx.

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that, elsewhere in the world,¹⁵¹ other legal systems are assimilating new scientific understandings and adapting accordingly. When viewed in a global perspective, our continued adherence to a prosecution template that rests on discredited science is particularly jarring.

What follows is an account of how we have arrived at this place.

A. Investigation and Prosecution

In the United States, unlike the United Kingdom and Canada, the SBS prosecution paradigm that ascended in the 1990s has remained largely untouched by scientific developments of the past decade.¹⁵² This systemic failure should not be equated with the prosecutorial pursuit of charges against defendants believed to be innocent of wrongdoing.¹⁵³ Rather, SBS cases are going forward because law enforcement officers genuinely believe in the validity of the diagnostic triad that has fallen from scientific grace.¹⁵⁴ But this explanation, while more benign than its alternative, begs the question of why the triad continues to exert an almost talismanic effect.¹⁵⁵

151. Apart from the institutional review mechanisms instituted by the United Kingdom and Canada, it is worth noting that Australia's criminal justice system has also begun to absorb new scientific understandings. In 2003, the Supreme Court of Western Australia issued an important decision in an SBS case. *R. v. Court* (2003) 308 WASC 1. At a bench trial for murder, the defendant was acquitted by a judge of all charges in a prosecution based on the presence of retinal hemorrhages and subdural hematoma, as well as spinal injury. *Id.* ¶¶ 1, 9. Central to the verdict was the court's reliance on the testimony of a prominent forensic pathologist, who testified that it was "not tenable" that the *only* possible cause of death was violent shaking. *Id.* ¶ 5. According to the trial judge,

[a]s I understand [the defense expert's] evidence, he was suggesting that unless a witness had seen the deceased being shaken or unless there was some medical evidence consistent with the child having been shaken, such as bruising or other external injury, or acceptable admissions, then to conclude that the deceased had died by being shaken in a prolonged or violent way was, as he expressed it, "highly suspect."

Id. The Supreme Court affirmed the reasonableness of this verdict. *Id.* ¶¶ 76, 95.

152. See *supra* notes 52–57 and accompanying text (discussing quantitative measures). Qualitative data also supports this proposition. Telephone Interview with Toni Blake, Jury Consultant, 2nd Chair Servs. (June 17, 2008); Telephone Interview with Brian Holmgren, Assistant Dist. Attorney, Davidson County Dist. Attorney Gen.'s Office, Child Abuse Unit (July 1, 2008).

153. While it is easy, and even fashionable, to vilify prosecutors, they are typically motivated by a desire to hold the guilty responsible for their actions. Many child abuse prosecutors seem almost missionary about their task, but this may come with the territory.

154. According to the database maintained by Toni Blake, see *supra* note 24, the vast majority of prosecutions go forward based solely on the presence of one or more triad symptoms. Telephone Interview with Toni Blake, *supra* note 152.

155. Apart from the dynamics discussed in the remainder of this Part, it must be noted that the death of an infant—the embodiment of innocence—inevitably provokes an intense emotional response among participants in the criminal process. It is quite reasonable that those affected would experience what Susan Bandes has insightfully described as an "urge to find an event blameworthy [in order] to

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It is worth noting the considerable deference given to child-abuse doctors¹⁵⁶—who, as a general rule, remain believers in the diagnosis.¹⁵⁷ Accordingly, prosecutors may exhibit a disinclination to interrogate the science upon which these physicians' opinions rest. There is nothing novel about the observation that prosecutors tend to defer to their experts; but, in this context, the relationship between the prosecutor and the allied medical professionals is a particularly close one.¹⁵⁸ In the typical SBS case, the expert *is* the case: there is no victim who can provide an account, no eyewitness, no corroborative physical evidence, and no apparent motive to kill.¹⁵⁹ Doctors identify both the occurrence of a crime and its perpetrator, and their assurance regarding each is essential for a conviction.¹⁶⁰ These dynamics may well contribute to a prosecutorial reluctance to challenge the validity of an SBS diagnosis. But they do not fully explain a continued willingness to pursue charges in cases built entirely on contested expert testimony.¹⁶¹

convert a loss into a crime." Interview with Susan A. Bandes, Distinguished Research Professor of Law, DePaul Univ. Coll. of Law, in Chi., Ill. (Oct. 16, 2008).

156. In 2006, "the American Board of Pediatrics approved a petition for subspecialty certification in child abuse pediatrics." Kent P. Hymel & Karen Seaver Hill, *Child Advocacy: New Board Specialty Signals Positive Change in Child Abuse Pediatrics*, CHILDREN'S HOSPITALS TODAY (2007), available at <http://www.childrenshospitals.net/AM/Template.cfm?Section=Archives&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=31157> (last visited May 6, 2009). The first board certification examination will take place in the fall of 2009. *Id.*

157. See Robert Parrish, *Prosecuting a Case*, in ABUSIVE HEAD TRAUMA: A MEDICAL, LEGAL, AND FORENSIC REFERENCE 393, 396–97 (Lori Frasier et al. eds., 2006) (noting that American Prosecutors Research Institute and other prosecutors are a good source of referral to experts in area).

158. In many cases, this relationship has been formalized in a manner unique to the child-abuse setting. As described by one leading expert on nationwide prosecutorial practices: Many local prosecutors across the country have formed or participate in interdisciplinary teams intended to bring together child protective service (CPS) workers, law enforcement investigators, medical professionals, mental health providers, educators, and others who play a role in ensuring that justice is appropriately sought for severely abused children. *Id.* at 395; see also Holmgren, *supra* note 25, at 276.

159. The hypothesis generally advanced by pediatricians and prosecutors is that shaking "results from tension and frustration generated by a baby's crying or irritability . . ." Am. Acad. of Pediatrics, *supra* note 18, at 206. See also Holmgren, *supra* note 25, at 289–90 ("Prosecutors will often not be able to point to a traditional 'motive' (e.g., hatred, jealousy, vengeance, greed) to explain the caretaker's conduct. Rather, they must reorient jurors to think about motive in a unique context—one that does not reflect a purposeful mental state but instead a risk factor, stressor or catalyst that prompts the caretaker's reactive and abusive conduct The most common motive in SBS cases is anger or frustration resulting from the infant's crying.")

160. The dominance of the "team approach to investigation," erodes a sharp differentiation between the roles of prosecutor and physician. Parrish, *supra* note 157, at 395–96. I found this to be true when, as a prosecutor, I participated in a medical grand rounds regarding a case that was the subject of one of my investigations.

161. Cognitive biases on the part of jurors, *infra* notes 243–47 and accompanying text, may also affect prosecutors.

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To complete the account, it is helpful to consider first, how prosecutors are trained in the science of SBS; second, how prosecutors perceive the accounts of those suspected of abuse; and, third, how prosecutors are influenced by the systemic nature of SBS convictions.

1. Prosecutorial Training

Training is especially critical in this area, where a complex and evolving body of science is outcome determinative.¹⁶² As one prominent instructor recently urged, “investigators and prosecutors should obtain a basic education on medical issues common to all of these cases.”¹⁶³ Since most prosecutors encounter SBS cases infrequently, few become experts in the issues they raise.¹⁶⁴ It is unsurprising, then, that a nationwide training apparatus has developed to disseminate information about the basic structure of an SBS prosecution. For instance, the American Prosecutors Research Institute of the National District Attorneys Association¹⁶⁵ transmits newsletters,¹⁶⁶ organizes conferences,¹⁶⁷ and

162. Parrish, *supra* note 157, at 395–96.

163. *Id.* at 395. “A fundamental understanding of the medical knowledge concerning AHT committed against children is absolutely essential to a prosecutor’s success in refuting commonly offered defenses, clarifying and dispelling myths introduced by opposing expert witnesses, and providing juries with sufficient information to reach a just decision.” *Id.* at 396.

164. “It is rare for a particular prosecuting attorney to handle multiple cases involving AHT [abusive head trauma] in child victims unless the prosecutor works in a specialized team assigned to handle physical abuse and child homicide.” *Id.* at 396. Even those prosecutors who do develop an expertise in this type of case “must be ever mindful that science is an ongoing process and medical research can quickly become dated Without a full understanding of the medical research that underlies an expert’s opinion, the prosecutor can neither make full use of the physician’s expertise, nor adequately cross-examine the opposing expert.” Holmgren, *supra* note 25, at 305.

165.

The mission of the American Prosecutors Research Institute is to provide state and local prosecutors knowledge, skills and support to ensure that justice is done and the public safety rights of all persons are safeguarded. To accomplish this mission, APRI serves as a nationwide, interdisciplinary resource center for research and development, technical assistance, training and publications reflecting the highest standards and cutting-edge practices of the prosecutorial profession.

American Prosecutors Research Institute, <http://www.ndaa.org/apri/index.html> (last visited July 21, 2009).

166. See, e.g., Erin O’Keefe, *Shaken Baby Syndrome: Overcoming Untrue Defenses*, 10 UPDATE 11 (1997), available at http://www.ndaa.org/publications/newsletters/update_index.html; Devon Lee et al., *Tips for Investigating Child Fatalities*, 13 UPDATE 1 (2000), available at http://www.ndaa.org/publications/newsletters/update_index.html; Victor I. Vieth, *Tips for Medical Professionals Called as Witnesses*, 13 UPDATE 7 (2000), available at http://ndaa.org/publications/newsletters/update_index.html.

167. Most recently, in July 2008, the National District Attorneys Association convened a conference on the “Investigation and Prosecution of Child Fatalities and Physical Abuse,” which

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provides other support for prosecuting the SBS case.¹⁶⁸ The National Center on Shaken Baby Syndrome, an organization dedicated in part to training law enforcement officers,¹⁶⁹ has hosted and collaborated on nine conferences since 2000.¹⁷⁰ And prosecutors who have become leaders in the field have published book chapters with instruction in handling SBS cases from investigation through trial.¹⁷¹

These training materials present a view of the science refracted through an advocate's lens. For instance, a 2001 publication asserts: "the [prosecution] expert can testify that the forces the child experiences are the equivalent of a 50–60 m.p.h. unrestrained motor vehicle accident, or a fall from 3–4 stories on a hard surface;"¹⁷² and "current research and professional consensus within the medical literature clearly supports the conclusion that . . . there is no lucid interval."¹⁷³ Similarly, from a chapter published in 2006: "there is emerging consensus among credible medical experts that when children have suffered serious or potentially fatal head injuries, they will start to experience symptoms almost immediately after injury;"¹⁷⁴ "[t]he collection of ocular damage, subdural or subarachnoid bleeding over the brain, axonal damage, and severe brain swelling is not seen in the same patterns in any forms of accidental trauma, but is seen in cases involving severe and violent shaking,"¹⁷⁵ and "the medical field has reached substantial consensus concerning many of the issues pertinent to criminal [SBS] cases."¹⁷⁶

While it should be expected that materials used to educate prosecutors would be strategically focused with respect to trial, this same orientation with respect to case investigation is more problematic. And while we might also anticipate that the most extreme critiques of the science underlying SBS convictions would be soundly—and passionately—attacked, many of these materials fail to acknowledge the shifting of the

included discussion of Abusive Head Trauma. More information may be found at http://www.ndaa.org/education/apri/investigation_child_fatalities_abuse_2008.html (last visited July 21, 2009).

168. See Parrish, *supra* note 157, at 396.

169. National Center on Shaken Baby Syndrome, About the Center, <http://www.dontshake.org/sbs.php?topNavID=2&subNavID=10> (last visited July 21, 2009).

170. National Center on Shaken Baby Syndrome, Conferences, <http://www.dontshake.org/sbs.php?topNavID=5&subNavID=38> (last visited May 6, 2009).

171. See generally Holmgren, *supra* note 25; Parrish, *supra* note 157.

172. Holmgren, *supra* note 25, at 307.

173. *Id.* at 305. See *id.* at 307 (stating that "the onset of symptoms is virtually contemporaneous with the abusive act").

174. Parrish, *supra* note 157, at 398.

175. *Id.* at 405.

176. *Id.* at 395.

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center. In defending the science of old,¹⁷⁷ the authors tend to obscure the changed consensus around fundamental aspects of the SBS diagnosis.¹⁷⁸ At the same time, significant challenges to the conventional medical wisdom are ignored.¹⁷⁹ Nomenclature aside,¹⁸⁰ few concessions to developments in research have been made. The digested science describes a diagnosis upon which prosecutors can securely rely.

2. Caregiver Accounts

Prosecutorial confidence in guilt is augmented by statements on the part of SBS suspects—statements which are inevitably perceived as incriminatory. The three accounts most often offered to explain an infant's loss of consciousness or other obviously severe neurological symptoms are that: (i) their onset was unprovoked/without explanation, (ii) the infant fell from a short distance, and (iii) the infant was shaken playfully or in the course of revival efforts.¹⁸¹ Research over the past decade has made each of these explanations newly plausible.¹⁸² But because law enforcement officers interrogating the SBS suspect “know” that the infant's injuries were caused by violent shaking—the science is believed to prove this definitively—the narratives are all perceived as false and, therefore, incriminating.¹⁸³

Moreover, if the suspect's story changes in response to familiar interrogation techniques,¹⁸⁴ this fact itself is used to support an SBS

177. See *supra* notes 172–76. Support for the assertions made in recent publications is often found in sources from the past that have since been challenged. For instance, a 2001 publication asserts that “the expert can testify that the forces the child experiences are the equivalent of a 50–60 m.p.h. unrestrained motor vehicle accident, or a fall from 3–4 stories on a hard surface” and cites evidence from the records of cases ranging from 1986–1994. Holmgren, *supra* note 25, at 307. In the same publication, the claim that “the onset of symptoms is virtually contemporaneous with the abusive act” is bolstered by studies from the 1990s. *Id.* See also *supra* note 173.

178. See *supra* notes 174–76 and accompanying text.

179. See *supra* notes 173–76 and accompanying text.

180. See *supra* notes 67–68 and accompanying text (discussing new diagnostic labels). Most notable, pathognomony as the defining feature of SBS has been supplanted by the more ambiguous claim that “retinal hemorrhages, bilateral subdural hematoma, and diffuse axonal injury are highly specific for SBS as a mechanism.” Holmgren, *supra* note 25, at 306.

181. Boos, *supra* note 14, at 50.

182. See *supra* Part III.B.3.

183. Holmgren, *supra* note 25, at 276 (“[T]he initial history provided by the caretaker is false in the vast majority of abuse cases and frequently evolves or changes over time as the caretaker is confronted with medical findings.”) (citations to scientific literature omitted).

184. See Leestma, *supra* note 80, at 14 (noting that the “interrogator may communicate to the accused that ‘if you could tell us exactly what happened and if you shook the baby, we could do something for the baby and maybe save its life.’”). While the particular tactics employed in the SBS context may be unique, the underlying techniques are not. See Richard A. Leo et al., *Bringing*

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diagnosis.¹⁸⁵ The ensuing interrogation confirms the suspect's guilt, as this veteran SBS prosecutor's characterization suggests: Each of the three most common histories, and others, may be combined in patterns of changing histories as guilty adults attempt to fabricate new explanations to respond to the probing or suggestive questions of one or multiple interviews.¹⁸⁶

But even if the caregiver's story remains constant, it too may be used as evidence of guilt.¹⁸⁷ The "discrepant history"—"when the history does not match the physical condition in front of you"—is also seen as proof that the infant was shaken.¹⁸⁸ Whatever contradicts the scientific "givens" is deemed "discrepant" and a confession.

In sum, law enforcement officers confirm their suspicions of SBS whenever a suspect provides "a false, discrepant, evolving *or* absent history."¹⁸⁹ The suspect cannot avoid self-incrimination; the investigator's certainty of guilt can only be reinforced.¹⁹⁰

Reliability Back In: False Confessions and Legal Safeguards in the Twenty-First Century, 2006 Wis. L. REV. 479, 512–20 (2006) (surveying empirical evidence on false confessions).

185. See, e.g., Carole Jenny et al., *Analysis of Missed Cases of Abusive Head Trauma*, 282 JAMA 621 (1999); Robert Reece, *Medical Evidence in the Context of Child Abuse Litigation*, NEW ENG. L. REV. 607, 610 (2002) ("[T]he history does not match the physical condition in front of you . . . Does the history fit what you see? If it does not, then you must question how such an injury could have occurred."). See also Anderson, *supra* note 55 (citing a nationally prominent pediatrician's observation, based on his consulting experience, that "[i]f a parent does not know exactly what's happening, very frequently the first conclusion is that they're trying to hide something. And sometimes parents are racking their brains, coming up with one or two possibilities. Then it looks like they're changing their stories. That can be used to damn them.").

186. See Boos, *supra* note 14, at 50 ("[W]hose story has evolved or changed to fit new information revealed by medical reports, medical personnel, or investigators?"); Parrish, *supra* note 157, at 416.

187. A model prosecutorial summation makes this point as follows: "it just couldn't happen the way the defendant says—not unless the laws of physics and gravity are different in the defendant's house. These doctors tell us that the defendant is a liar . . . A defendant who lies to protect himself points the finger of guilt upon himself." Holmgren, *supra* note 25, at 325.

188. Reece, *supra* note 61, at 610. Put differently, "[t]he false histories help identify the likely individual who caused the child's injuries by providing compelling evidence of the abuser's consciousness of guilt." Holmgren, *supra* note 25, at 277.

189. Holmgren, *supra* note 25, at 277.

190. Consider the dynamics reflected in the following interrogation of a day care provider suspected (based on the presence of the triad) of shaking a six-month-old infant to death. According to the caregiver's initial account, after leaving the children unattended for a short time, she returned to find a toddler sitting on the neck of the baby, who was having trouble breathing. After waiving her *Miranda* warnings, the caregiver (Rogers) was told by the interrogating officer (Wheeler) that: according to a "panel of doctors," a child "could not have caused" the baby's injuries; that "anyone could have been pushed 'over the top' by all of the children in Rogers's care," and "if Rogers was just overwhelmed, then that was 'explainable'"; that Wheeler "already knew something 'aggressive' happened, but now she just needed to know why," that "only an adult could have inflicted the force necessary to hurt [the baby] in this manner and that the injury occurred close to the time that [the baby] began seizing," when only Rogers was present; that "if [police] could not go to the doctors with a logical explanation for what happened, then it looked 'very, very bad' for Rogers; and that Rogers's

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3. Reification

Finally, prosecutorial thinking about these cases is pervaded by an echo of the methodological fallacy of the early SBS literature.¹⁹¹ If, across the country over the years, defendants have been proven guilty of shaking babies to death based on the presence of retinal hemorrhages, subdural hematomas and cerebral edemas, then the presence of these symptoms must mean that someone is guilty of shaking a baby to death. All that remains is to identify the last person with the conscious child. That person becomes the suspect, who can then be confidently pursued. In this manner, the triad-based crime constructed by the medical establishment¹⁹² has been reified—its existence affirmed—by the systematic conviction of its apparent perpetrators.¹⁹³

B. Evidentiary Challenges

Defense motions to exclude expert testimony regarding SBS have, almost without exception, proven unsuccessful.¹⁹⁴ Despite new challenges to the scientific underpinnings of the diagnosis, the admission of SBS testimony is facilitated by its once-uncontroversial nature. Even recently, and in cases involving triad symptoms alone, courts in both *Daubert* and

story “had to match the medical evidence.” Two hours after the interview began, Rogers confessed to shaking the baby and (“she thought”) repeatedly slamming his head on the floor. She was arrested, charged and convicted of intentional child abuse resulting in death, and sentenced to life imprisonment.

In an extraordinary decision, the Nebraska Supreme Court reversed the defendant’s conviction due to a violation of her Fifth Amendment right against self-incrimination. Specifically, the court held that Rogers had invoked her right to silence, and that this invocation was not scrupulously honored by the police. The case will be tried later this year. Telephone Interview with Tim Burns, Douglas County Pub. Defender’s Office (June 10, 2009).

191. The cognitive dissonance resulting from having prosecuted people whose guilt has now been scientifically undermined should not be discounted. But here I am identifying a dynamic that is more systemic.

192. See *supra* Part III.A.

193. This dynamic has likely been perpetuated by media coverage of always sensational “baby-killing” cases. See *supra* note 40. See also Vanessa Bauza, *Abusive Shaking Top Killer of Babies; Police Say Infant Latest Area Victim*, SUN SENTINEL (Fort Lauderdale, Fla.), Oct. 4, 1999.

194. In the course of my research, I have not been made aware of any case in which the testimony of defense experts challenging the basis for an SBS diagnosis was excluded on *Daubert* or *Frye* grounds. See *infra* note 195 for a summary of the *Daubert* and *Frye* standards. Prosecutors are either declining to make these challenges or are making them unsuccessfully. See Holmgren, *supra* note 25, at 316 (“There is no scientific research which supports the re-bleed theory of causation in very young children. . . . Accordingly, the application of this theory to infants should be challenged on *Frye* and *Daubert* grounds.”).

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Frye jurisdictions¹⁹⁵ have rejected arguments that SBS is not generally accepted in the medical community¹⁹⁶ and that it is not based on reliable scientific methods.¹⁹⁷

Given the importance placed on the criterion of general acceptance within the “relevant” scientific community—even in *Daubert* jurisdictions, where it is not dispositive—the consensus among pediatricians has been given particular emphasis by admitting trial judges.¹⁹⁸ In the absence of legally binding precedent, judges are well aware that “for some time, courts in other states have found shaken baby syndrome to be a generally accepted diagnosis in the medical community.”¹⁹⁹ Judges have also noted that research into SBS has been peer reviewed, and that there has been “considerable literature put out by professional scientific organizations that substantiate the findings.”²⁰⁰ While at least one court has explicitly recognized “[t]he absence of a

195.

Two approaches [to the admissibility of scientific testimony] are dominant—general acceptance [*Frye*] and scientific soundness [*Daubert*]. Under the former, the proponent must show that the scientific community agrees that the principles or techniques on which the expert relies are capable of producing accurate information and conclusions. Under the latter standard, general acceptance remains an important consideration, but the court must consider other factors to decide for itself whether the expert’s methodology is scientifically valid.

CHARLES MCCORMICK ET AL., MCCORMICK ON EVIDENCE 335 (Kenneth S. Brown et al. eds., 6th ed. 2006).

196. See, e.g., *Middleton v. State*, 980 So. 2d 351, 353 (Miss. Ct. App. 2008) (defendant contended that “Shaken Baby Syndrome is not a condition or theory that is generally accepted in the medical community”).

197. See, e.g., *State v. Leibhart*, 662 N.W.2d 618, 623 (Neb. 2003) (defendant argued “that the theory of shaken baby syndrome as a cause of certain injuries was not supported by reliable scientific authority, data, or research”).

198. See, e.g., *id.* at 627–28 (SBS “is generally accepted within the scientific medical community of pediatrics”) (internal quotations omitted). The *Leibhart* court concluded that

[w]ith respect to general causation, the district court did not abuse its discretion in concluding on this record that the reasoning or methodology underlying testimony regarding shaken baby syndrome was valid, and with respect to specific causation, the district court did not abuse its discretion in concluding that such reasoning or methodology properly could be applied to the facts in issue in this case.

Id. at 628.

199. *Id.* at 628 (citing *State v. Lopez*, 412 S.E.2d 390 (S.C. 1991); *State v. McClary*, 541 A.2d 96 (Conn. 1988); *In re Lou R.*, 499 N.Y.S.2d 846 (N.Y. Fam. Ct. 1986)). See also *State v. Vandemark*, No. 04-01-0225, 2004 Del. Super. LEXIS 376, at *8–9 (Del. Super. Ct. 2004) (“[I]t seems that the science behind Shaken Baby Impact Syndrome has been accepted in Delaware and just about every other jurisdiction.”). See Holmgren, *supra* note 25, at 306 (“Expert testimony involving a diagnosis of SBS is well recognized and does not need to satisfy the *Daubert* or *Frye* Standards governing the admissibility of expert testimony or novel scientific evidence.”).

200. *Leibhart*, 662 N.W.2d. at 627 (internal quotation omitted).

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known rate of error,” this void was dismissed as merely “reflect[ing] the limitations of the subject matter.”²⁰¹

The standards for determining the admissibility of scientific evidence in effect privilege the institutionalized theoretical framework—even despite serious doubts about the validity of underlying methodologies. Perhaps judicial reluctance to keep testimony regarding SBS from the jury derives from faulty evaluations of the science, or from an overly deferential respect for the establishment that recommends it. But it is also quite likely that judges are allowing this type of testimony because our justice system is structured in a way that makes its admission the default. “[T]he standard for admissibility is relevance and reliability, not certainty,” as courts often remark when allowing SBS testimony.²⁰²

As is widely recognized, the law of evidence is fundamentally premised on the functioning of our adversary system. As the United States Supreme Court emphasized in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, “[v]igorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof are the traditional and appropriate means of attacking shaky but admissible evidence.”²⁰³ Courts often justify the admission of SBS testimony by reference to this foundational principle. For instance: “The ‘gate-keeping function of the court was never meant to supplant the adversarial trial process. The fact that experts disagree as to methodologies and conclusions is not grounds for excluding relevant testimony;”²⁰⁴ “[a] party confronted with an adverse expert witness who has sufficient, though perhaps not overwhelming, facts and assumptions as the basis for his opinion can highlight those weaknesses through effective cross-examination.”²⁰⁵

Admissibility determinations are also grounded in the proper allocation of decision-making authority between judge and juror. In a recent reversal on interlocutory appeal of a trial judge’s order excluding the prosecution’s

201. *Vandemark*, 2004 Del. Super. LEXIS 376, at *16–17. Discussing a particular study where the rate of false positives (i.e., cases incorrectly diagnosed as abuse) was admittedly unknown, the trial judge noted that “no suggestion was made about how to structure [a more rigorous] analysis.” *Id.* at *16. In *Leibhart*, the court made a similar observation regarding the limits of the science proffered by the prosecution: “it [has] been clinically tested as the best it can.” *Leibhart*, 662 N.W.2d at 627.

202. See, e.g., *People v. Martinez*, 74 P.3d 316, 322 (Colo. 2003).

203. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 596 (1993).

204. *Commonwealth v. Martin*, Nos. 2006-CA-002236-MR, 2006-CA-002237-MR, 2008 WL 2388382, at *7 (Ky. Ct. App. June 13, 2008) (quoting *LP Matthews LLC v. Bath & Body Works, Inc.*, 458 F. Supp. 2d 198, 210 (D. Del. 2006)).

205. *Id.* at *8 (quoting *Stecyk v. Bell Helicopter Textron, Inc.*, 295 F.3d 408, 414 (3d Cir. 2002)).

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SBS testimony, this consideration was explicitly invoked.²⁰⁶ “The gatekeeping function of the trial court is restricted to keeping out unreliable expert testimony, not to assessing the weight of the testimony. This latter role is assigned to the jury.”²⁰⁷ Even more emphatically, “[t]he court is *only* a gatekeeper, and a gatekeeper alone does not protect the castle”²⁰⁸

Systemic factors construct a presumption of admissibility: if the evidence is not “pseudoscientific” or “junk science,”²⁰⁹ it comes in. This presumption is overcome only rarely by still-evolving research.²¹⁰ In recent years, testimony regarding SBS has been excluded only twice.²¹¹ In Kentucky, after hearing from experts on both sides, a trial court concluded that the diagnosis “presupposes the cause.”²¹² The court’s order continued: “To allow a physician to diagnose SBS with only the two classical markers, and no other evidence of manifest injuries, is to allow a physician to diagnose a legal conclusion.”²¹³ Accordingly, the judge precluded the state from presenting expert testimony regarding SBS based exclusively on subdural hematoma and retinal hemorrhage and in the absence of “any other indicia of abuse.”²¹⁴ As noted, this order was subsequently

206. According to the appellate court, the trial judge’s order was an abuse of discretion, because it was founded on the unsupported legal conclusion that because there was dispute amongst the experts as to the possible cause of the infants’ injuries, it was the court’s role to choose the side it found more convincing and exclude the side it found less convincing, based in part on giving greater weight to “scientific” as opposed to “clinical” studies. *Id.* at *7. For further discussion of the evidentiary ruling in *Martin*, see *infra* notes 212–16 and accompanying text.

207. *Martin*, 2008 WL 2388382, at *7.

208. *Id.* at *8 (quoting *United States v. Mitchell*, 365 F.3d 215, 245 (3d Cir. 2004)).

209. *Id.* at *7 (noting that testimony of prosecution experts, “even accepting . . . its flaws” cannot be so described).

210. *State v. Leibhart*, 662 N.W.2d 618, 628 (Neb. 2003) (reexamination under *Daubert* appropriate “where recent developments raise doubts about the validity of previously relied-upon theories”) (citation omitted).

211. This conclusion is based on searches of the LEXIS database and the web, as well as my conversations with the likely participants in these litigation efforts. Telephone Interview with John Plunkett, *supra* note 41; Telephone Interview with Toni Blake, *supra* note 152; Telephone Interview with Brian Holmgren, *supra* note 152. In addition to the two admissibility decisions discussed above, a few trial courts have disallowed experts from using the SBS terminology. For instance, a judge in Ohio precluded reference to SBS, concluding that testimony to this effect would improperly usurp the role of the jury. The prosecution expert was, however, allowed to testify “as to the characteristics of the injuries suffered by a child believed to have been subjected to rotational acceleration/deceleration.” Renee Brown, *Judge Denies Reference to Syndrome During Trial*, TIMES REPORTER (New Phila., Ohio) (on file with author).

212. Order and Opinion Re: *Daubert* Hearing, *Kentucky v. Davis*, Case No. 04-CR-205 at *21 (Ky. Cir. Ct. Apr. 17, 2006).

213. *Id.* at *23.

214. *Id.*

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reversed.²¹⁵ The defendant has appealed the decision to the state supreme court.²¹⁶

The other court to exclude SBS evidence did so in a case also involving a diagnosis based on retinal hemorrhage and subdural hematoma.²¹⁷ After hearing testimony from experts on both sides, the Missouri trial judge determined that the SBS diagnosis “appears to have gained considerable acceptance . . . among pediatricians. However, there is substantial, persistent and continuing criticism of this diagnosis among many in the medical and scientific research communities.”²¹⁸ In its unpublished order, the court concluded that the state had failed to meet its burden of establishing that SBS is generally accepted in the scientific and medical communities.²¹⁹ The state was thus precluded from offering testimony that the infant was a victim of violent shaking based on the diagnostic triad alone.²²⁰ This ruling was not appealed.²²¹

Although the two trial court decisions to exclude testimony about SBS are outliers, they foretell more aggressive defense challenges to the

215. *Commonwealth v. Martin*, Nos. 2006-CA-002236-MR, 2006-CA-002237-MR, 2008 WL 2388382, at *9 (Ky. Ct. App. June 13, 2008).

216. The appeal to the Kentucky Supreme Court was filed on July 14, 2008 and is pending as the Article goes to print. The “CaseInfo” sheet for *Martin* is available at http://apps.kycourts.net/coa_public/CaseInfo.aspx?Case=2006CA002236.

217. Order, *State v. Hyatt*, No. 06M7-CR00016-02 (Mo. Cir. Ct. Nov. 6, 2007). In *Hyatt*, the one-year-old who was being cared for by the defendant was released from the hospital without lasting injury. The caregiver has been charged with abuse of a child for “knowingly inflict[ing] cruel and inhuman punishment upon [the baby] by shaking her, and in the course thereof . . . caus[ing] serious emotional injury. . . .” The felony is punishable by five to fifteen years in prison. Felony Complaint, *State v. Hyatt*, No. 06M7-CR00016-02 (on file with author).

218. Order, *supra* note 217. The court further noted: “The critics contend that subdural hematoma and retinal bleeding can have many other causes and that the diagnosis of shaken baby syndrome is merely a ‘default’ diagnosis, one which pediatricians use when they have no other explanation for the cause of the child’s injuries.” *Id.*

219. *Id.* Missouri is a *Frye* jurisdiction. Request for ‘Frye’ Hearing and Brief in Support of Request, *State v. Hyatt*, No. 06M7-CR00016-02 (Mo. Cir. Ct.) (on file with author).

220.

The Court therefore finds that in the absence of some other evidence or indicia of abuse besides subdural hematoma, retinal bleeding and absence of cranial trauma, neither party may call a witness to give an expert opinion that the child was the victim of violent shaking; the Court further finds that an expert may not opine that a (small) subdural hematoma and retinal bleeding in an infant can only be caused by manual shaking.

Order, *supra* note 217.

221. Nevertheless, the state attempted to proceed on the theory that previously occurring injuries (i.e., a small bruise and scrape) constituted “other indicia of abuse.” Telephone Interview with Kirk Zwink, Esq., Sole Practitioner, Karl Zwink Law Office (July 21, 2008). According to Kirk Zwink, who represented Kathy Hyatt, the state’s evidence at trial included claimed inconsistencies in the defendant’s account, as well as the expert testimony of two pediatricians. *Id.* The defendant testified and presented an expert pathologist on her behalf. After a three-day trial in January 2009, the jury returned its verdict within a half hour: not guilty. *Id.*

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admissibility of the science, as well as greater pressure on judges to restrict the scope of expert testimony. If research in this area continues to erode the foundations of the diagnosis, evidentiary rulings will evolve accordingly—but only after a lag guaranteed by judicial deference to precedent, to physicians, and to the workings of the adversary system. For now, with few exceptions, if an SBS case goes to trial, juries will decide the worth of the science and the fate of the accused.

C. Jury Verdicts

Little is known about the operation of juries in shaken baby cases.²²² One national trial consultant who assists the defense in this area has estimated a conviction rate of 95%;²²³ a prosecutor widely recognized as a national authority on SBS has suggested that the figure is closer to 50%;²²⁴ and a forensic pathologist who has consulted on many hundreds of cases for the defense places the figure somewhere between the two.²²⁵ In the absence of meaningful empirical documentation,²²⁶ the impressionistic data of those who see the largest number of these cases—and have done so for at least a decade—becomes a helpful source of information.

Such experts in SBS trial outcomes seem to agree upon certain basic propositions. Juries continue to convict based on medical testimony about the triad of symptoms.²²⁷ They are, however, acquitting more frequently today than ever before.²²⁸ Although the most important predictor of an

222. “Typically, a jury verdict in a criminal case is inscrutable; the jury performs its paradigmatic function as fact finder shrouded in secrecy, and it is impossible to say why or how the jury convicted or acquitted in any given case.” Julie A. Seaman, *Black Boxes*, 58 EMORY L.J. 427, 432 (2008). For reasons already discussed, the “black box” nature of the jury may well be compounded in the SBS context. See *supra* note 148 (observing that ascendance of the prosecution paradigm has gone largely unnoticed and remarking on a corresponding failure to collect data).

223. Telephone Interview with Toni Blake, *supra* note 152. As a basis for comparison, for an analysis of overall conviction rates, see Andrew D. Leipold, *Why are Federal Judges so Acquittal Prone?*, 83 WASH. U. L.Q. 151 (2005). See also Daniel Givelber, *Lost Innocence: Speculation and Data about the Acquitted*, 42 AM. CRIM. L. REV. 1167 (2005).

224. Telephone Interview with Brian Holmgren, *supra* note 152.

225. Telephone Interview with John Plunkett, *supra* note 41 (estimating conviction rate of 1/2 to 2/3 of cases tried).

226. The National Center on Shaken Baby Syndrome keeps no centralized database, and no other organization tracks prosecutions. The largest database containing this type of information belongs to Toni Blake, the leading trial consultant in this area. Blake’s database contains over 500 SBS cases from 1997–2007. Telephone Interview with Toni Blake, *supra* note 152.

227. Where there is medical corroboration of abuse beyond the triad—e.g., rib fractures, grip marks, long bone fractures, and evidence of injuries in various stages of healing—the case is often resolved by a guilty plea before trial. See *supra* note 41.

228. Telephone Interview with Toni Blake, *supra* note 152; Telephone Interview with Brian Holmgren, *supra* note 152; Telephone Interview with John Plunkett, *supra* note 41. For an account of

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acquittal is the defense presentation of nationally prominent experts who challenge the science,²²⁹ the presentation of this type of evidence still results in conviction more often than acquittal.²³⁰ Therefore, while an increasing reliance on defense experts²³¹ and a growing population of such experts for defendants to draw on²³² should be expected to result in a greater number of acquittals proportionally, there is every reason to believe that SBS-based convictions will persist.

In prosecutions that rely on science to prove causation, *mens rea* and identity, how can jurors faced with genuine scientific debate as to each of these elements be convinced of guilt beyond a reasonable doubt? To make sense of this question, consider how the prosecution's burden of proof may be effectively eased, first, by the skepticism that greets the "differential diagnosis" offered by the defense experts²³³ and, second, by the sheer inertial force of SBS.

The current state of the science does not typically allow the defense to identify one cause with certainty. Instead, experts provide a complex forensic analysis. From the defendant's perspective, the differential diagnosis is strategically important because it provides an alternative version of events—albeit a less definitive one—that gives jurors a different way of thinking about what happened. But the differential diagnosis is also dangerous, as it tends to functionally shift the prosecutor's burden of proving its theory of the case onto the defense.²³⁴

The state's winning argument to juries is this: *the defendant has not established what caused the child's death while the prosecution experts are in full agreement regarding their diagnosis. They told you what the three presenting symptoms mean—how they are caused, how much force is*

one recent acquittal, see Wendy Davis, *Danforth Woman Found Not Guilty of First Degree Murder*, WATSEKA TIMES REPUBLIC, Mar. 3, 2009.

229. Toni Blake has also suggested that mothers are convicted at the highest rates. Telephone Interview with Toni Blake, *supra* note 152.

230. *Id.*; Telephone Interview with Brian Holmgren, *supra* note 152; Telephone Interview with John Plunkett, *supra* note 41.

231. As noted by the expert who is widely credited (or, depending on perspective, maligned) for spearheading the movement of SBS skeptics, the more doctors a defendant can afford, the greater the likelihood of an acquittal. Telephone Interview with John Plunkett, *supra* note 41. While the equity concerns raised by SBS cases are not unique to this context, they may be particularly acute where, as here, the science dictates outcomes.

232. The minority view is becoming more prevalent. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 70; Testimony of George R. Nichols in Transcript of Evidentiary Hearing (Day One) at 170, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. 2008) (No. 96 CF 555); Telephone Interview with John Plunkett, *supra* note 41; Interview with Thomas Bohan, *supra* note 78.

233. See *supra* notes 132–36 and accompanying text.

234. A specifically crafted jury instruction could explain the interplay between defense evidence of a differential diagnosis and the prosecution's burden of proof.

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required, and how soon after the trauma the baby would have lost consciousness. The defense experts gave you a list of various possibilities, but admitted that they could not be sure about what happened here. And, indeed, they did not even agree amongst themselves regarding this child's death.²³⁵

In the *Edmunds* post-conviction hearing, where the determination for a judge was whether new scientific research would probably result in a different outcome at trial,²³⁶ the prosecutor made this appeal: "The primary flaw [in the defendant's theory of post-conviction relief] is the fact—and it's not an opinion; it is a fact—that no one on this defense team could agree on the cause of death in this case."²³⁷ Indeed, no defense expert testified to certainty regarding any particular theory of death.²³⁸

This reasoning would seem to have considerable traction with jurors.²³⁹ Indeed, the differential diagnosis—or, from the perspective of the prosecution, "a veritable laundry list of alternative medical possibilities which are commonly proffered" by the defense²⁴⁰—has become a critical area of contention in SBS trials.²⁴¹

The defense must concede that it cannot definitively prove a mechanism of injury.²⁴² According to the accused in an SBS case, testimony regarding other plausible diagnoses is important not because it definitively establishes the occurrence of a scenario other than the one

235. For sample prosecutorial closing argument in SBS case, see Holmgren, *supra* note 25, at 324–27. See also Attorney for the State in Transcript of Oral Argument at 89–90, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. 2008) (No. 96 CF 555) ("It might be interesting, it might be fun for the defendant to have the jury speculate, but that's not what we do in courts of law.").

236. More precisely, the court must determine "whether a reasonable probability exists that a different result would be reached at trial." *Edmunds*, 2008 WI App 33, ¶ 13, 746 N.W.2d 590, ¶ 13 (citation omitted). See *infra* Part IV.E.1.

237. Attorney for the State in Transcript of Oral Argument, *supra* note 235, at 75–76. The prosecutor reiterated this point later in the argument: "the mud balls; throw, throw, see if something sticks. Differential Diagnosis." *Id.* at 87–88.

238. See, e.g., Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 71.

239. As one prosecutor has instructed, "[d]efenses are frequently focused on other possible medical explanation for the injuries. A responsive theme might be that 'arguments derived from possibilities are idle.'" Holmgren, *supra* note 25, at 288.

240. *Id.* at 314. See *id.* at 319 ("The expert who acknowledges the classic findings of SBS include subdural hematoma, retinal hemorrhage and edema, but chooses to ignore this constellation of findings in favor of an alternative hypothesis will appear foolish."); *id.* at 312–19 (discussion of "meeting untrue defenses and cross-examination of defense experts").

241. See Parrish, *supra* note 157, at 410 (suggesting prosecutorial strategy for dealing with defense experts' testimony regarding differential diagnosis).

242. Edmunds acknowledged as much in her post-conviction relief hearing, but argued that this burden was not properly hers: "The state says in terms of differential diagnosis, bring it home . . . [p]rove your other causes. Well, this . . . puts the burden backwards. We don't have a burden of proving some alternative cause." Attorney for the Defense in Transcript of Oral Argument, *supra* note 115, at 141. See *id.* at 138.

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hypothesized by the prosecution, but because it casts doubt on the claim that no other scenario *could* explain the symptoms.

This mode of argument tends to be deeply unsatisfying to the human psyche and, as a consequence, problematic for jury decision making. It is widely recognized that “fact finders look for stories, not just discrete nuggets of fact to fit into a set of legal rules.”²⁴³ Burdens of proof notwithstanding, a consensus that identifies a single narrative will almost invariably trump an amalgam of possibilities that challenge it.²⁴⁴ In SBS cases, what the defense asks the jury to do is surmount this psychological barrier²⁴⁵ and acquit.

The likelihood of this occurring is diminished by the context in which the medical dispute is presented to jurors. In a typical SBS case, as a matter of law, the prosecution must establish that the presence of retinal hemorrhages, subdural hematoma, and cerebral edema proves beyond a reasonable doubt that the defendant on trial shook the baby to death. If the science cannot bear this burden, the jury must acquit—even in the absence of a known cause.²⁴⁶ The reality is quite different on the ground, where, to prevail at trial, a defendant must disprove the validity of a medical diagnosis with impressive establishment *bona fides*.

Until only recently, SBS had been embraced nearly unanimously by the scientific community, and it still commands the faithful adherence of a majority of physicians. To the general public, the diagnosis has come to be understood as a meaningful marker of criminality. Substance aside, these measures of acceptance serve as powerful proxies for truth, enabling jurors to discount the insights of the skeptics and the challenges raised by their research.

243. Mary I. Coombs, *Telling the Victim's Story*, 2 TEX. J. WOMEN & L. 277, 288 (1993).

244. I have previously observed that “verdicts reflect which narrative was more persuasive to the jury.” Deborah Tuerkheimer, *Recognizing and Remediating the Harm of Battering: A Call to Criminalize Domestic Violence*, 94 J. CRIM. L. & CRIMINOLOGY 959, 981 (2004).

245. This type of reasoning is “speculative,” *see supra* note 235, insofar as it requires jurors to reach a verdict in the absence of a proven causal mechanism. But thus defined, where the prosecution’s version of events has not been adequately established, a speculative verdict is completely appropriate, and indeed dictated by the presumption of innocence. Put differently, SBS defendants who challenge the science do not advance any particular explanation as the definitive cause of death, but, rather, insist that since a number of possibilities could have been causal, the prosecution cannot satisfy its burden of proof. The jury need not speculate that any one of the alternatives is in fact *the cause*; the very existence of alternatives negates proof of inflicted injury beyond a reasonable doubt.

246. As Edmunds’s attorney argued in her post-conviction relief hearing, the “evidence is now there that undermines the state’s ability to prove the mechanism and timing of death.” Attorney for the Defense in Transcript of Oral Argument, *supra* note 115, at 138.

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D. Insufficiency Claims

Defendants challenging the sufficiency of the evidence against them in SBS cases²⁴⁷ focus on two areas of arguably deficient proof: mens rea,²⁴⁸ and causation/identity.²⁴⁹ While many prosecutions involve physical evidence of other abuse (i.e., beyond shaking) apart from the triad,²⁵⁰ a substantial number rests solely on the presence of retinal hemorrhaging and subdural hematoma.²⁵¹ Even in this latter subcategory, courts are invariably affirming convictions.²⁵²

247. Defendants may move for a judgment of acquittal based on an insufficiency of the evidence at the conclusion of the prosecution's case, after the defense has rested, and again after the jury has returned its verdict. A denial of this motion is given considerable deference, but is reviewable on direct appeal or on collateral attack. While the applicable legal standards differ, claims that a conviction rests on insufficient evidence raise similar issues across jurisdictional and procedural contexts.

248. See Charles A. Phipps, *Responding to Child Homicide: A Statutory Proposal*, 89 J. CRIM. L. & CRIMINOLOGY 535, 551-74 (1999) (discussing mental states associated with traditional homicide statutes used to prosecute defendants under SBS theory). For a sampling of cases from just this past year, see, e.g., Mitchell v. State, No. CACR 07-472, 2008 Ark. App. LEXIS 98 (Ark. Ct. App. Feb. 6, 2008); People v. Lemons, No. 273058, 2008 Mich. App. LEXIS 387 (Mich. Ct. App. Feb. 26, 2008); State v. Gilbert, No. M2007-00260-CCA-R3-DC, 2008 Tenn. Crim. App. LEXIS 326 (Tenn. Crim. App. Apr. 8, 2008).

249. See, e.g., U.S. v. Dimberio, 56 M.J. 20 (C.A.A.F. 2001); State v. Cort, 766 A.2d 260 (N.H. 2000). See also *infra* notes 257-68.

250. See, e.g., People v. Frank, No. A109619, 2007 Cal. App. Unpub. LEXIS 3777 (Cal. Ct. App. May 10, 2007); People v. Heredia, No. A112828, 2007 Cal. App. Unpub. LEXIS 9537 (Cal. Ct. App. Nov. 28, 2007); Moore v. State, 656 S.E.2d 796 (Ga. 2008); State v. Hollins, 981 So. 2d 819 (La. Ct. App. 2008); State v. Hill, 250 S.W.3d 855 (Mo. Ct. App. 2008); State v. Batich, No. 2006-A-0031, 2007 Ohio App. LEXIS 2127 (Ohio Ct. App. May 11, 2007); Commonwealth v. Hardy, 918 A.2d 766 (Pa. Super. Ct. 2007); State v. Sweet, No. E2007-OD202-CCA-R3-PC, 2008 Tenn. Crim. App. LEXIS 280 (Tenn. Crim. App. Apr. 15, 2008); Hammond v. State, No. 2-06-417-CR, 2008 Tex. App. LEXIS 969 (Tex. Ct. App. Feb. 7, 2008).

While this Article is largely concerned with triad-based SBS prosecutions, it bears mentioning that even cases involving proof apart from the triad may be problematic. Some physical evidence is of questionable corroborative value. See, e.g., People v. Montgomery, No. 269957, 2007 Mich. App. LEXIS 2412 (Mich. Ct. App. Oct. 23, 2007) (bruise on right temple). Moreover, even where the physical evidence clearly indicates abuse, the identity of the perpetrator may be disputed. See, e.g., People v. Garcia, No. H023327, 2003 Cal. App. Unpub. LEXIS 3479 (Cal. Ct. App. Apr. 7, 2003). In *Garcia*, the defense expert testified to preexisting injuries unrelated to head trauma. *Id.* at *10. He "agreed that [the baby] was a battered child, that his injuries were nonaccidental, and that his death was a homicide. But he believed that it was impossible to determine with medical certainty whether the injuries that caused his death occurred shortly before the time of death or whether death resulted from complications from earlier patterns of injuries." *Id.* Finally, reliance on perpetrator "confessions" to prove guilt may be misplaced. See *supra* Part IV.A.2.

251. See, e.g., People v. Jackson, No. D049865, 2007 Cal. App. Unpub. LEXIS 9866 (Cal. Ct. App. Dec. 6, 2007); Middleton v. State, 980 So. 2d 351 (Miss. Ct. App. 2008).

252. In the past year, the only court to reverse an SBS conviction did so because the defendant was denied effective assistance of counsel. In *Schoonmaker*, the New Mexico Supreme Court noted that "[e]xpert testimony was critical to the defense to call into question the State's expert opinions that [the child's] injuries could only have been caused by shaking of a violent nature." State v. Schoonmaker, 176 P.3d 1105, 1113 (N.M. 2008). Based on the testimony of defense experts in other

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Deference to the fact-finding functions of juries translates into a legal regime generally hostile to insufficiency arguments.²⁵³ In the evidentiary context, this judicial deference is exercised at the front-end of the trial process; here it comes at the back-end, after the prosecution has rested, after the defense has rested, and/or after the jury has returned its guilty verdict.²⁵⁴ The governing standard on appeal is “whether, considering the evidence in a light most favorable to the prosecution, *any* rational trier of fact could have found the essential elements of the offense charged beyond a reasonable doubt.”²⁵⁵ It is thus to be expected that defendants rarely persuade courts to overturn SBS-based convictions on sufficiency grounds.²⁵⁶

cases and published scientific research, the court found that “disagreement exists in the medical community as to the amount of time between when injuries occur and when the child becomes symptomatic, and whether injuries like [the child’s] can be caused by short-distance falls. . . .” *Id.* at 1114. It was clear, therefore, that the defendant’s failure to call experts to testify on his behalf was due not to the absence of supporting science, but to poverty. *Id.* at 1113–16. In a remarkable opinion, the court concluded that because of the trial courts’ role in “deny[ing] counsel access to the necessary funding,” the defendant was entitled to a new trial. *Id.* at 1114.

In another appeal based on ineffective assistance, the Utah Supreme Court in 2007 reversed a murder conviction based on defense counsel’s failure to retain a qualified expert to examine CT scans of the infant’s injuries. *State v. Hales*, 152 P.3d 321 (Utah 2007). In *Hales*, SBS was diagnosed based on brain swelling and retinal hemorrhages. *Id.* at 326. According to the State’s expert, these injuries could only have been caused by violent shaking which would have caused immediate unconsciousness with no possibility of a lucid interval. *Id.* at 329. In support of his motion, the defendant submitted the affidavit of a pediatric neuroradiologist stating that, based upon his (post-conviction) review of the CT scan, it would have been impossible for trauma to have occurred during the time period in which the defendant was with the baby. *Id.* In response to the court’s ruling, the state determined that there was insufficient evidence to proceed with further prosecution. Stephen Hunt, *New Evidence Frees Inmate in Murder Case*, SALT LAKE TRIBUNE, June 16, 2007.

253. “The basic problem seems to be that judges do not want to look as though they are abrogating the role of the jury as trier of fact. The legal sufficiency of evidence is, technically, a question of law, but it looks and sounds like a judgment on the weight of the evidence—it is a judgment on the weight of the evidence, only an extreme one.” Samuel R. Gross, *Substance & Form in Scientific Evidence: What Daubert Didn’t Do*, in REFORMING THE CIVIL JUSTICE SYSTEM 234, 252 (Larry Kramer ed., 1996).

254. See *supra* note 247 (detailing procedural postures of various types of sufficiency challenges).

255. *State v. Gilbert*, No. M2007-00260-CCA-R3-CD, 2008 Tenn. App. LEXIS 326 (Tenn. Crim. App. Apr. 8, 2008) (citations omitted).

256. In the rare instance where an appellate court has reversed a SBS conviction, it has done so on other grounds. See, e.g., *United States v. Gaskell*, 985 F.2d 1056 (11th Cir. 1993) (prejudicial in-court shaking demonstration with baby doll); *People v. Basuta*, 94 Cal. App. 4th 370 (Cal. Ct. App. 2001) (evidentiary); *Andrews v. State*, 811 A.2d 282 (Md. 2002) (same); *State v. Maze*, No. M2004-02091-CCA-R3-CD, 2006 WL 1132083 (Tenn. Crim. App. Aug. 28, 2006) (failure to instruct on lesser-included charges); *Schoonmaker*, 176 P.3d 1105 (ineffective assistance of counsel); *Caban v. State*, No. 5D08-279, 2009 WL 722049 (Fla. Dist. Ct. App. Mar. 20, 2009) (improper impeachment of defense expert).

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Shirley Ree Smith may be the only defendant to succeed in doing so.²⁵⁷ Her case is extraordinary, particularly because the procedural context in which the claim arose—an appeal of a denial of Smith’s federal habeas petition—makes the result exceedingly unlikely.

In certain respects, the facts of *Smith* diverge from the paradigmatic SBS pattern. The defendant was the child’s grandmother.²⁵⁸ The medical evidence showed an absence of retinal bleeding.²⁵⁹ Most significantly, pathologists found “no swelling, and only a small, non-fatal amount” of subdural and subarachnoid bleeding.²⁶⁰

But in other ways, the facts share important similarities with the typical triad-only SBS prosecution. No bruises on the body, fractures, or grip marks were present.²⁶¹ The accused claimed to have discovered the infant in a nonresponsive state.²⁶² The “discrepant history” was considered evidence of guilt.²⁶³ The prosecution experts’ testimony was “absolutely critical to its case.”²⁶⁴

Even under the highly deferential standard mandated on federal habeas review,²⁶⁵ a three-judge panel of the Ninth Circuit concluded that this evidence was insufficient to sustain a guilty verdict: “There was simply no

257. I reach this conclusion based on a thorough search of the LEXIS database and my conversations with leaders on both sides of nationwide litigation efforts.

258. As the court remarked,

[t]his is not the typical shaken baby case. Grandmothers, especially those not serving as the primary caretakers, are not the typical perpetrators. Further, Petitioner was helping her daughter raise her other children (a 2-year-old and a 14-month-old) and there was no hint of Petitioner abusing or neglecting these other children, who were in the room with [the baby] when he died.

Smith v. Mitchell, 437 F.3d 884, 889 (9th Cir. 2006).

259. *Smith*, 437 F.3d at 887. Notwithstanding this observation, it is important to note that SBS-based convictions in the absence of retinal hemorrhages are routinely affirmed on appeal. *See, e.g.*, *People v. Jackson*, No. D049865, 2007 Cal. App. Unpub. LEXIS 9866 (Cal. Ct. App. Dec. 6, 2007); *State v. Humphries*, No. 06CA00156, 2008 Ohio App. LEXIS 315 (Ohio Ct. App. Feb. 4, 2008).

260. *Smith*, 437 F.3d at 887.

261. The only external injury was “recent small abrasion, approximately 1/16 by 3/16 of an inch, on the lower skull, upper neck region, and a recent bruise beneath this abrasion.” *Id.*

262. *Id.* at 886.

263. Smith apparently told police that she had given the baby a “jostle” to rouse him and responded, “Oh my God, Did I do it?” to a social worker when informed that the baby had died of shaking. *Id.* at 889 n.11.

264. *Id.* at 890.

265. *Jackson v. Virginia*, requires courts to determine whether “after viewing the evidence in the light most favorable to the prosecution, any rational trier of fact could have found the essential elements of the crime beyond a reasonable doubt.” *Jackson v. Virginia*, 443 U.S. 307, 319. The Antiterrorism and Effective Death Penalty Act (AEDPA) even more “severely restricts” the scope of review of state court decisions, as it “mandates that [courts] apply the standards of *Jackson* with an additional layer of deference . . . and only grant habeas relief where the state court’s adjudication of a *Jackson* claim is objectively unreasonable.” *Smith v. Mitchell*, 453 F.3d 1203, 1203–06 (9th Cir. 2006) (Bea, J., dissenting) (internal citation omitted).

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demonstrable support for shaking as the cause of death [T]here has very likely been a miscarriage of justice in this case.”²⁶⁶

The court’s reasoning in this regard is instructive on when a deficiency in proof rises to the level requiring reversal:

All of the prosecution witnesses based their opinion of Shaken Baby Syndrome on their hypothesis that violent shaking had torn or sheared the brain stem in an undetectable way^[267] [A]nd they reached this conclusion because *there was no evidence in the brain itself of the cause of death*. Thus . . . the tearing might have occurred or it might not have occurred; there simply was no evidence to permit an expert conclusion one way or the other on the point. This is simply not the stuff from which guilt beyond a reasonable doubt can be established²⁶⁸

The improbability of a court substituting its view of the sufficiency of the evidence for the jury’s in this manner—and of that ruling being left intact—is indicated by *Smith*’s highly unusual procedural path. The defendant’s conviction was affirmed by the state appellate court.²⁶⁹ The California Supreme Court denied review.²⁷⁰ The federal magistrate judge recommended that the habeas petition be denied and the district court denied the petition.²⁷¹ After the three-judge panel reversed this denial and the full court voted to deny a petition for rehearing en banc, a number of

266. *Smith*, 437 F.3d at 890. “With all due respect to the California Court of Appeal, and even with the additional layer of deference mandated by AEDPA, we conclude that the Court of Appeal unreasonably applied *Jackson* when it held the evidence to be sufficient to convict Smith of causing [the child’s] death.” *Id.*

267. *See infra* note 268 (further discussing disputed significance of lack of visible shearing in brain stem).

268. *Smith*, 437 F.3d at 890. A number of Ninth Circuit judges criticized the panel for “adopt[ing] the defense experts’ view of what physical evidence is necessary to support a valid diagnosis of shaken baby syndrome.” *Smith*, 437 F.3d at 1207 (Bea, J., dissenting). The judges who would have affirmed Smith’s conviction had a very different view of the evidence against her:

The physicians called by the prosecution reached their conclusion *despite* the lack of visible shearing, not because of it, and explained why. Indeed, what provided the basis for the doctors’ opinions was the evidence of recent trauma to [the child’s] brain: (1) the subdural hemorrhaging; (2) the subarachnoid hemorrhaging; (3) the hemorrhaging around the optic nerves; (4) the blood clot between the hemispheres of [the child’s] brain, and (5) the bruise and abrasion at the lower back of [the child’s] head. The prosecution’s experts considered and rejected other causes of [the child’s] death Since none of these alternate theories explained [the child’s] death, the prosecution’s doctors opined that [he] died from violent shaking, as evidenced by the trauma.

Id. at 1206.

269. *Id.*

270. *Id.*

271. *Id.*

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judges wrote to dissent bitterly.²⁷² The United States Supreme Court then granted *certiorari*, vacated the judgment, and remanded the case for further consideration²⁷³ in light of a recent decision elaborating on the standard applicable to federal habeas review of a state court affirmation of conviction.²⁷⁴ After the Ninth Circuit reinstated its earlier judgment and opinion,²⁷⁵ the state once again petitioned the Supreme Court for review.²⁷⁶ This petition is currently pending as this Article goes to print.²⁷⁷

Now compare *Smith* to the far more typical case of Drancy Deshann Jackson, whose conviction was recently affirmed on direct appeal by a California court.²⁷⁸ Jackson is currently serving a prison term of thirteen years for felony child abuse.²⁷⁹ The medical evidence consisted of subdural hemorrhaging and diffuse brain swelling—no retinal hemorrhages, no other injuries—which prosecution experts diagnosed as

272. *Id.* (“[T]he opinion is inaccurate.”); *id.* at 1207–08 (“Under our court’s approach, a federal court of appeals may, effectively, set aside an expert opinion where it conflicts with the views of the other side’s experts.”).

273. *Patrick v. Smith*, 550 U.S. 915 (2007).

274. *Carey v. Musladin*, 549 U.S. 70 (2006).

275. *Smith v. Patrick*, 508 F.3d 1256 (9th Cir. 2007). The court’s rationale for reinstating the opinion is emphatic:

Nothing in the State’s failure of evidence takes this case out of the class of cases subject to the test of *Jackson*. Unlike *Musladin* . . . this case presents merely one more instance where the evidence presented by a state is wholly insufficient to permit a constitutional conviction. *Jackson* makes clear that such cases cannot constitutionally stand if the evidence was insufficient “to convince a trier of fact beyond a reasonable doubt of the existence of every element of the offense.” . . . *Jackson* makes clear that a conviction is unconstitutional even if there is *some* evidence of guilt when all of the evidence, viewed in the light most favorable to the prosecution, does not permit any rational fact-finder to find guilt beyond a reasonable doubt. *Smith*’s case accordingly falls squarely within *Jackson*. Moreover, the prosecution’s evidence falls so far short that it was unreasonable for the state appellate court to conclude that it met the *Jackson* standard.

Id. at 1258–59 (citations omitted).

276. Petition for Writ of Certiorari, *Patrick v. Smith*, No. 07-1483 (9th Cir. May 27, 2008).

277. Whether the Court decides to review the case may depend on its assessment of the following reasoning advanced by the Ninth Circuit:

It is true, of course, that the Supreme Court has never had a case where the issue was whether the evidence, expert and otherwise, was constitutionally sufficient to establish beyond a reasonable doubt that a defendant had shaken an infant to death. But there are an infinite number of potential factual scenarios in which the evidence may be insufficient to meet constitutional standards. Each scenario theoretically could be construed artfully to constitute a class of one. If there is to be any federal habeas review of constitutional sufficiency of the evidence as required by *Jackson*, however, [AEDPA] cannot be interpreted to require a Supreme Court decision to be factually identical to the case in issue before habeas can be granted on the ground of unreasonable application of Supreme Court precedent. The Supreme Court does not interpret AEDPA in such a constrained manner.

Smith v. Patrick, 508 F.3d at 1259.

278. *People v. Jackson*, No. D049865, 2007 Cal. App. Unpub. LEXIS 9866 (Cal. Ct. App. Dec. 6, 2007).

279. *Id.* at *1.

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SBS.²⁸⁰ The defendant's account—that the baby fell from the couch where he had been propped with a bottle—was dismissed as “inconsistent” with the observed symptoms.²⁸¹

The defense presented evidence that Jackson was an “excellent parent who never abused or hit his children or any other child for whom [he] was the caretaker.”²⁸² The baby's pediatrician testified that “there was no evidence [the baby] had been abused” prior to the incident in question.²⁸³ The sole defense expert, a biomechanical engineer, questioned the scientific basis for SBS.²⁸⁴ Citing research showing that short-distance falls can cause subdural hematomas, he also noted “that it was an open question whether an earlier injury could make the child more susceptible to injury from a second fall.”²⁸⁵

Applying the familiar standard of review,²⁸⁶ the appellate court determined that:

[t]he conflict among the experts' opinions . . . did not render the evidence insufficient. . . . In finding [against the defendant], the jury necessarily rejected his experts' contention The credibility and weight of the expert testimony was for the jury to determine, and it is not up to us to reevaluate it. The jury could reasonably believe the evidence of the prosecution witnesses and reject that of the defense witness.²⁸⁷

280. *Id.* at *4–5. Other prosecutions have gone forward on the basis of subdural hematomas alone. *See, e.g.,* *People v. Collier*, No. A120808, 2009 WL 389721 (Cal. Ct. App. Feb. 18, 2009) (affirming conviction). Prosecutors have also proceeded on the basis of retinal hemorrhages (without subdural hematoma). *See, e.g.,* *Hess v. Tilton*, No. CIV S-07-0909, 2009 WL 577661 (E.D. Cal., Mar. 5, 2009) (affirming conviction).

281. *Jackson*, 2007 Cal. App. Unpub. LEXIS 9866, at *13.

282. *Id.* at *8.

283. *Id.*

284. *Id.* at *5–6.

285. *Id.* at *6.

286. The standard was described in *Jackson* as follows:

When reviewing a claim attacking the sufficiency of the evidence to support a conviction, the question we ask is “whether, after viewing the evidence in the light most favorable to the prosecution, any rational trier of fact could have found the essential elements of the crime beyond a reasonable doubt.” As an appellate court, we “must view the evidence in a light most favorable to respondent and presume in support of the judgment the existence of every fact the trier could reasonably deduce from the evidence.” . . . A conviction will not be reversed for insufficient evidence unless it appears “that upon no hypothesis whatever is there sufficient substantial evidence to support [the conviction].” . . . “If the circumstances reasonably justify the trier of fact's findings, the opinion of the reviewing court that the circumstances might also be reasonably reconciled with a contrary finding does not warrant a reversal of the judgment.”

Id. at *9–10 (citations omitted).

287. *Id.* at *13 (citations omitted).

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As the reasoning of the *Jackson* court evinces, the legal framework governing sufficiency challenges seems to virtually preordain this result.²⁸⁸ Credibility determinations are within the province of the jury; when the testimony of defense experts is rejected, that rejection must be afforded deference by the appeals court. Provided that the prosecution experts testify in a manner that reasonably justifies a finding of guilt, the conviction is affirmed.²⁸⁹

In short, a conflict in expert opinions is functionally irrelevant to the disposition of sufficiency challenges. Given this, the legal landscape will not be appreciably altered by a louder chorus of SBS skeptics, but by continued movement in this direction on the part of the SBS faithful. If the testimony of *prosecution* experts comes to reflect the scientific limitations of a triad-based diagnosis of abuse, a court may well conclude that evidence of SBS is “not the stuff from which guilt beyond a reasonable doubt can be established. . . .”²⁹⁰

Even in the midst of continued scientific controversy, this judicial shift may yet occur.²⁹¹ Despite deep tensions within the competing opinions,²⁹² *Smith* suggests that the trial record must contain evidence of a sufficient quantum and caliber. According to the Ninth Circuit, habeas relief was warranted because “[a]n expert’s testimony as to a *theoretical conclusion or inference* does not rescue a case that suffers from an underlying

288. For a recent example of this phenomenon, see *Thomas v. State*, No. 03-07-00646-CR, 2009 WL 1364348, at *7 (Tex. App. May 14, 2009) (“Sharply conflicting evidence was presented regarding the scientific basis of shaken baby syndrome and, consequently, the diagnosis of the State’s witnesses Once admitted, this conflicting evidence presents an issue for the jury to resolve.”). The same is true of manifest weight challenges. See *State v. Humphries*, No. 06CA0015b, 2008 Ohio App LEXIS 315, at *23–24 (Ohio Ct. App. Feb. 4, 2008) (“[A] conviction is not against the manifest weight of the evidence solely because the jury heard inconsistent testimony.”) (internal quotations omitted). In *Humphries*, the court affirmed the child endangerment conviction of Latasha Humphries for the death of her child, whose SBS diagnosis was based on subdural hematoma and cerebral edema alone. *Id.* at *12. Humphries was identified as the perpetrator based on a perceived impossibility of a lucid interval, as well as the defendant’s “fail[ure] to provide a reasonable explanation for [the child’s] injuries. . . .” *Id.* at *22. Only one expert testified on behalf of the defendant. *Id.* at *2. See *supra* note 231 (noting significance of presenting more than one expert). The opinion references marijuana use, *Humphries*, 2008 Ohio App. Lexis, at *5, the defendant’s status as an unmarried mother, and the impoverished environment in which the child was being raised (e.g., “dingy one piece pajamas,” crib missing one side, *id.* at *9–10)—factors which may well have disadvantaged Humphries at trial and on appeal.

289. As Samuel Gross has observed in the civil context, “traditionally courts have held that the testimony of any qualified expert is sufficient to sustain a verdict on any issue on which she testified.” Gross, *supra* note 233, at 252.

290. *Smith v. Mitchell*, 437 F.3d 884, 890 (9th Cir. 2006).

291. In what may indicate an overall trend in this direction, trial consultant Toni Blake noted that, in 2007, “we saw one of these cases overturned about once a month.” Anderson, *supra* note 55.

292. See *supra* notes 268, 272 and accompanying text.

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insufficiency of evidence to convict beyond a reasonable doubt.”²⁹³ But the “absence of evidence”²⁹⁴ cited by the court—an absence which “cannot constitute proof beyond a reasonable doubt”²⁹⁵—is, more precisely, an absence of evidence worthy of conviction. Identifying the qualitative judgment embodied in this determination is not to indict it. After all, even the “rational trier of fact” to whom courts are deferring must have certain standards.²⁹⁶ In triad-only SBS cases, judges willing to assess the value of the state’s evidence, as the court did in *Smith*, may conclude that an absence of evidence has convicted others.

E. Post-Conviction Proceedings

1. Edmunds

In early 2007, the judge who presided over Audrey Edmunds’s trial over a decade earlier conducted a five-day evidentiary hearing in support of her motion for a new trial based on newly discovered evidence. The defense experts²⁹⁷ testified that, since the mid-1990s, “significant research has undermined the scientific foundations for SBS, creating substantial challenges to matters that were nearly universally accepted in the medical community at the time of Edmunds’s trial.”²⁹⁸

According to the defense experts, a still-emerging body of literature had cast new doubt on previously accepted medical dogma.²⁹⁹ Now in dispute: whether shaking alone can cause the constellation of injuries associated with SBS;³⁰⁰ whether a specific mechanism for the injuries (i.e., shaking) can be accurately identified;³⁰¹ whether considerable force, as opposed to a minor impact, is necessary to cause the injuries associated with the syndrome;³⁰² whether previously unrecognized mimics of child abuse can cause the triad of symptoms said to be pathognomonic of

293. *Smith*, 437 F.3d at 890 (emphasis added).

294. *Id.*

295. *Id.*

296. *Id.* at 885.

297. The following physicians testified as experts for the defense: the chief of pediatric neuroradiology at Stanford’s Children’s Hospital; the former Chief Medical Examiner for Kentucky; a forensic pathologist; a pediatrician; an ophthalmologist; and the autopsy pathologist who testified at Edmunds’s trial as a prosecution witness. Transcript of Evidentiary Hearing (Days One and Two), *State v. Edmunds*, 746 N.W.2d 590 (2008) (No. 96 CF 555).

298. Brief of Defendant, *supra* note 4, at 11.

299. *Id.* at 3 (“[T]he science that sent Audrey Edmunds to prison did not stand still.”).

300. *Id.* at 13–16.

301. *Id.*

302. *Id.* at 20.

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abusive head trauma;³⁰³ and whether the occurrence of the type of head trauma leading to serious brain damage inevitably causes immediate unconsciousness.³⁰⁴

The defense experts testified that “in 1996 they themselves would have testified as the State’s experts had at Edmunds’s trial,”³⁰⁵ but the evolving science had changed their opinions as to the likely cause of death.³⁰⁶ In short, the scientific foundation for concluding beyond a reasonable doubt that Edmunds had shaken Natalie Beard to death was no longer intact.³⁰⁷ The near unanimity that once characterized the medical establishment’s understanding of SBS had been shattered.³⁰⁸ Yet no new medical accord had been reconstituted in its place.³⁰⁹ Against this disquieting backdrop, Audrey Edmunds’s new trial motion was decided.

303. *Id.* at 16–20.

304. *Id.* at 20–23.

305. *Id.* at 11.

306. Regarding the particular circumstances of Natalie’s death, the defense experts testified that the evidence upon which Edmunds was convicted had been undermined by a number of scientific developments: studies using biomechanical models, animal models, and computer simulations suggested that Natalie’s brain injuries could not have been caused by shaking alone; even if Natalie’s death were caused by trauma (i.e., impact), considerably less force than previously suspected could have caused her injuries; new research had uncovered a number of causes of the retinal hemorrhages which, at trial, were said to conclusively prove that Natalie had been shaken; emerging science revealed that chronic subdural hematomas—like the one discovered at Natalie’s autopsy—may re-bleed with little precipitation, causing further brain injury; the differential diagnosis (a range of possible explanations for Natalie’s injuries other than abusive head trauma) had evolved considerably in recent years; and, finally, the evidence thought to be dispositive on the timing of injuries was contradicted by a number of “lucid interval” studies, undermining past certainty that Natalie was injured during the hour that she was in Edmunds’ care. *Id.* at 14–23.

307. The appellate court summarized the evidentiary record of the post-conviction hearing as follows:

Edmunds presented evidence that was not discovered until after her conviction, in the form of expert medical testimony, that a significant and legitimate debate in the medical community has developed in the past ten years over whether infants can be fatally injured through shaking alone, whether an infant may suffer head trauma and yet experience a significant lucid interval prior to death, and whether other causes may mimic the symptoms traditionally viewed as indicating shaken baby or shaken impact syndrome. Edmunds could not have been negligent in seeking this evidence, as the record demonstrates that the bulk of the medical research and literature supporting the defense position, and the emergence of the defense theory as a legitimate position in the medical community, only emerged in the ten years following her trial.

State v. Edmunds, 2008 WI App 33, ¶ 15, 746 N.W.2d 590, ¶ 15.

308. Even the state’s experts acknowledged, to varying degrees, that scientific consensus about SBS had changed since the mid-1990s. *See State v. Edmunds*, No. 96 CF 555, slip op. at 7 (Wis. Cir. Ct. Mar. 29, 2007) (“Expert witnesses on both sides now indicate that research about Shaken Baby Syndrome has evolved . . .”); *supra* Part III.B.

309. The defense experts maintained that Natalie’s death was caused by some combination of violent shaking and impact, and that this trauma could only have been inflicted immediately prior to the onset of unmistakable and severe neurological damage. Brief Plaintiff-Respondent at 35–37, *State v. Edmunds*, 746 N.W. 2d 590 (Wis. Ct. App. 2008) (No. 2007AP000933) [hereinafter “State’s brief”].

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While expressly acknowledging that “[s]tanding alone and unchallenged, the defense witnesses provide[d] a sufficient evidentiary basis to order a new trial based upon newly discovered medical evidence,”³¹⁰ the trial judge denied the motion. But an appellate court reversed this decision and concluded that there was a reasonable likelihood that a different result would be reached at a new trial.³¹¹

In a remarkable opinion without judicial precedent, the court noted the “shift in mainstream medical opinion since the time of Edmunds’s trial.”³¹² While there were “now competing medical opinions as to how Natalie’s injuries arose and . . . the new evidence does not completely dispel the old evidence,”³¹³ the court was persuaded that “the emergence of a legitimate and significant dispute within the medical community as to the cause of those injuries that constitutes newly discovered evidence.”³¹⁴ According to the appeals court,

[at trial,] the State was able to easily overcome Edmunds’s argument that she did not cause Natalie’s injuries by pointing out that the jury would have to disbelieve the medical experts in order to have a reasonable doubt as to Edmunds’s guilt. Now, a jury would be faced with competing credible medical opinions in determining whether there is a reasonable doubt as to Edmunds’s guilt. Thus, we conclude

310. *Edmunds*, No. 96 CF 555, slip op. at 6 (Wis. Cir. Ct. Mar. 29, 2007). Nevertheless, the court engaged in a deliberate balancing of the defense evidence against the evidence offered by the state in rebuttal. After having “look[ed] at all the evidence from the trial as well as the evidence presented by both sides on defendant’s motion for a new trial,” it concluded that “[t]he newly discovered evidence presented by the defense is significantly outweighed by the evidence presented by the prosecution.” *Id.* at *10–11.

311. The appellate court held that the trial judge had incorrectly applied the law, and that this error constituted an abuse of discretion:

After determining that both parties presented credible evidence, it was not the court’s role to weigh the evidence. Instead, once the circuit court found that Edmunds’s newly discovered medical evidence was credible, it was required to determine whether there was a reasonable probability that a jury, hearing all the medical evidence, would have a reasonable doubt as to Edmunds’s guilt. This question is not answered by a determination that the State’s evidence was stronger. . . . [A] jury could have a reasonable doubt as to a defendant’s guilt even if the State’s evidence is stronger.

Edmunds, 2008 WI App 33, ¶ 18, 746 N.W. 2d 590, ¶ 18. Noting that the trial judge had already made its credibility determinations, the appeals court proceeded to apply the correct legal standard itself rather than remand the case. *Id.* ¶ 19. On April 14, 2008, Wisconsin Supreme Court denied the petition for review. *State v. Edmunds*, 749 N.W.2d 663 (Wis. 2008).

312. *Edmunds*, 2008 WI App 33, ¶ 23, 746 N.W.2d 590, ¶ 23.

313. *Id.* “Indeed, the debate between the defense and State experts reveals a fierce disagreement between forensic pathologists, who now question whether the symptoms Natalie displayed indicate intentional head trauma, and pediatricians, who largely adhere to the science as presented at Edmunds’s trial.” *Id.*

314. *Id.*

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that the record establishes that there is a reasonable probability that a jury, looking at both the new medical testimony and the old medical testimony, would have a reasonable doubt as to Edmunds's guilt.³¹⁵

Audrey Edmunds was granted a new trial.³¹⁶ Months later, all charges against her were dismissed.³¹⁷

2. Beyond Edmunds

Enormous procedural and substantive hurdles confront defendants at the post-conviction stage.³¹⁸ Although the law differs depending on jurisdiction, a number of generalizations can be made about the SBS defendant's burden of proof. Put simply, there are tensions between the governing framework for collateral relief and the issues presented by SBS cases.³¹⁹ These strains were nicely illustrated by the state's arguments against post-conviction relief in *Edmunds*.

First, the evidence presented at the post-conviction stage must be deemed new, or "discovered" after the trial.³²⁰ One problem for the

³¹⁵. *Id.*

³¹⁶. *Id.*

³¹⁷. On July 11, 2008, the state announced its decision to dismiss charges against Edmunds. Ed Trevelen, *Citling Wishes of Baby's Parents, Prosecutors Won't Retry Edmunds*, WIS. STATE J., July 11, 2008.

³¹⁸. This discussion is confined to newly discovered evidence claims, which are most relevant to SBS cases given the trajectory of the underlying science. "[E]very state currently permits at least some form of post-trial relief on the basis of newly discovered evidence." Daniel S. Medwed, *Up the River Without a Procedure: Innocent Prisoners and Newly Discovered Non-DNA Evidence in State Courts*, 47 ARIZ. L. REV. 655, 659 (2005) (citing 1 Donald E. Wilkes, Jr., *State Postconviction Remedies and Relief: With Forms*, 1-13, at 55-58 (2001) (all states provide a direct remedy in the form of a new trial motion based on newly discovered evidence). Newly discovered evidence "represents a ground for relief through the principal state post-conviction remedies in thirty-two states." *Id.* at 682.

Apart from *Edmunds*, I am aware of only two SBS cases where post-conviction relief was granted. In each, murder charges were ultimately dismissed, albeit on somewhat different grounds. One defendant's conviction was overturned in 2004 based on the discovery of flaws in the autopsy. *Dad Freed from Life Sentence in Son's Death*, ORLANDO SENTINEL (Fla.), Aug. 28, 2004, at A1, available at <http://articles.mercola.com/sites/articles/archive/2004/09/18/yurko-case.aspx>. That same year, charges against another defendant were dismissed by a newly elected District Attorney after an extensive review of "new evidence that point[ed] to reasonable doubt." Maura Dolan, *Fatal Abuse or Tragedy Compounded?*, L.A. TIMES, June 16, 2006, at A1.

³¹⁹. I focus here on the legal standards applicable to these claims, as opposed to the formidable procedural barriers to collateral relief. These barriers have been criticized by Professor Daniel Medwed, who has proposed reforms targeted at greater systemic embrace of newly discovered non-DNA evidence, including abolishing statute of limitations, allowing innocence claims to be heard by a new judge, and creating a de novo standard of appellate review for summary dismissals of newly discovered evidence motions. Medwed, *supra* note 318, at 686-715.

³²⁰. *Edmunds*, 2008 WI App 33, ¶ 13, 746 N.W.2d 590, ¶ 13. Related to this is the requirement that the defendant's failure to discover the evidence is not the result of negligence, which raises issues

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defense is that the proffered evidence is less definitive than past “scientific improvement[s]”³²¹—DNA typing, primarily.³²² In *Edmunds*, the prosecutor underscored this point: the defense could offer no “bone test . . . [that] would tell us whether that infant was . . . the subject of [shaking-inflicted] brain injury.”³²³ Instead, the evidence was described as “an academic debate among medical experts,”³²⁴ and one the prosecution characterized as ongoing at the time of the trial in order to negate a showing of “newness.”³²⁵ For instance, the article widely recognized as the “classic that really set this all in motion about doubting shaking,”³²⁶ was published in 1987,³²⁷ and a small number of scientists were already questioning the basis for SBS in the early 1990s.³²⁸ The state thus argued that “[t]he debate . . . was fully engaged” at the time of trial.³²⁹ Although the court rejected this characterization,³³⁰ future defendants collaterally attacking their convictions may have greater difficulty satisfying the “newly discovered” requirement if the evidence offered as “new” at the post-conviction stage was more fully developed when the trial occurred.³³¹

similar to those presented by the “newly discovered” standard. *Id.* See *infra* notes 323–33 and accompanying text.

321. Attorney for State in Transcript of Oral Arguments (Day 5) at 69, *State v. Edmunds*, 746 N.W.2d 590 (Wis. Cir. Ct. Mar. 8, 2007) (No. 96 CF 555).

322. Defendants making newly discovered evidence motions face impediments to relief that are very much situated against the backdrop of DNA exonerations. See *infra* notes 343–50 and accompanying text (DNA as paradigm of newly discovered evidence).

323. Attorney for State in Transcript of Oral Arguments, *supra* note 321, at 69.

324. State’s brief, *supra* note 309, at 17. Compare *id.* at 17 (“*Edmunds*’ newly discovered evidence claim is a ‘non-starter’ because, despite two days of expert testimony, she failed to present clear and convincing evidence of anything ‘new’ here.”) with Defendant’s brief, *supra* note 4, at 35–36 (“The new evidence demonstrates that the scientific basis for SBS theory is under serious challenge.”).

325. State’s brief, *supra* note 306, at 18–22.

326. Barnes testimony, Evidentiary Hearing (Day One), *supra* note 71, at 97 (referencing Duhaime study, *supra* note 120).

327. Duhaime, *supra* note 120.

328. At least one physician, Dr. John Plunkett, has been doing so for decades. Telephone Interview with John Plunkett, *supra* note 41; Interview with Thomas Bohan, *supra* note 78.

329. State’s brief, *supra* note 309, at 21.

330. “While there may have been strands of disagreement about Shaken Baby Syndrome present in 1996, studies, research, debate and articles about the concept have grown exponentially since the trial . . . All the defense experts indicated they would have agreed with the prosecution’s theory if they had been testifying in 1996.” *State v. Edmunds*, No. 96 CF 555, slip op. at 6 (Wis. Cir. Ct. Mar. 29, 2007). The appellate court affirmed this aspect of the ruling. See *supra* note 307.

331. *Edmunds*, unlike most defendants requesting post-conviction relief, was also able to point to the fact that the autopsy pathologist retracted important portions of his trial testimony. See Defendant’s brief, *supra* note 4, at 24 (“Perhaps most significantly, Dr. Huntington retracted key parts of his 1996 testimony—both on the certainty that Natalie was shaken, and the assessment that there could have been no significant lucid interval.”); *supra* note 115 (explaining basis for Huntington’s conversion).

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Second, the evidence must be material to the case and not merely cumulative.³³² The prosecution in *Edmunds* asserted that the “academic debate” about SBS was “beside the point”,³³³ theoretical disagreements about whether shaking alone could cause death and whether the triad alone was pathognomonic of abuse were irrelevant to Edmunds’s conviction, given the severity of the infant’s injuries.³³⁴ The court could dispense with this argument in short order,³³⁵ given that the prosecution fell squarely within the SBS paradigm—the cause of death was said to be forceful shaking, the diagnosis was made on the basis of the classic triad,³³⁶ and the perpetrator was identified based on the impossibility of a lucid interval.³³⁷ But given the current state of scientific research, which (unlike DNA³³⁸) cannot conclusively establish a defendant’s innocence, deviations from this prototypical fact pattern will tend to undermine the defendant’s materiality claim.

Finally, the evidence must probably have resulted in a different verdict at trial.³³⁹ This is the most difficult burden for the defense,³⁴⁰ and was predictably the greatest area of contention in the *Edmunds* post-conviction relief proceedings.³⁴¹ The defense argued to the court that, at trial,

[t]he jury never had any reason to doubt that diagnosis of shaking, with or without impact, and nearly immediate collapse was unassailable as medical evidence. This is simply no longer true [T]his new evidence of evolving science that rigorously challenges

332. *Edmunds*, 2008 WI App 33, ¶ 13, 746 N.W.2d 590, ¶ 13.

333. State’s brief, *supra* note 309, at 33.

334. “The severity of the injuries sustained by Natalie takes this case out of the classic ‘triad’ mold. Not only did Natalie sustain retinal bleeding, she sustained retinal folds and retinoschisis.” *Id.* at 27.

335. “The evidence is material to an issue in the case because the main issue at trial was the cause of Natalie’s injuries, and the new medical testimony presents an alternate theory for the source of those injuries.” *Edmunds*, 2008 WI App 33, ¶ 15, 746 N.W.2d 590, ¶ 15.

336. According to prosecution experts, differences between retinal hemorrhages—in terms of extent, location, and pattern—are significant. *See, e.g.*, Testimony of Alex Levin in Transcript of Evidentiary Hearing (Day Four), *supra* note 129, at 99–101.

337. Defendant’s brief, *supra* note 4, at 40 (“[T]he science was the whole case, and new research seriously challenges the foundations of the scientific case”).

338. *See infra* notes 343–51 and accompanying text (discussing DNA as “new evidence” paradigm).

339. *Edmunds*, 2008 WI App 33, ¶ 13, 746 N.W.2d 590, ¶ 13.

340. *See* State’s brief, *supra* note 309, at 16 (“[T]he hardest requirement to meet is that the offered evidence in view of the other evidence would have probably resulted in an acquittal.” (quoting *Lock v. State*, 142 N.W.2d 183 (Wis. 1966))).

341. “The real crux of the dispute in this case is whether the new expert medical testimony Edmunds offers establishes a reasonable probability that a different result would be reached in a new trial.” *Edmunds*, 2008 WI App 33, ¶ 16, 746 N.W.2d 590, ¶ 16. Here the trial judge sided with the state. *See supra* note 310.

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and refutes long-presumed hypotheses . . . very well could change the outcome. . . .³⁴²

In refuting this notion, the prosecutor explicitly juxtaposed the scientific attacks on SBS with the certainty of DNA exonerations. Unlike the new debate offered by the defense, DNA was “real science” that established innocence “to an astronomical degree of science (sic) or statistical probability.”³⁴³ DNA did not “dispute a theory or demonstrate a rift or a contention in the scientific community. It didn’t provide for alternative hypotheses.”³⁴⁴ In contrast to defense evidence substantiating the existence of lucid intervals, DNA samples “exclude[d] the defendant from the world of possible perpetrators.”³⁴⁵ And unlike testimony regarding possible alternative causes of death in *Edmunds*, DNA provided definitive answers.³⁴⁶

As the *Edmunds* arguments show, DNA has implicitly been positioned as the paradigm of newly discovered evidence. Although the appeals court ultimately rejected the prosecutor’s arguments, DNA’s reign as the “poster child of newly discovered evidence” motions³⁴⁷ must be reckoned with. The level of certitude DNA provides has become a *de facto* “benchmark,”³⁴⁸ and the actual innocence it establishes is a touchstone for post-conviction relief.³⁴⁹ As a consequence, legal standards may be formulated and applied in ways that tend to disadvantage other types of proof. As a matter of law, DNA is not the benchmark³⁵⁰ and actual

342. Attorney for the Defense in Transcript of Oral Argument, *supra* note 115, at 58.

343. Attorney for the Prosecution in Transcript of Oral Argument, *supra* note 321, at 65.

344. *Id.*

345. *Id.* at 105.

346. The prosecutor in *Edmunds* argued this point as follows: “Is there an enzyme that still exists in the bones of this deceased child that will tell us if she was the subject of rotational acceleration-deceleration injury that killed her? No.” Attorney for the Defense in Transcript of Oral Argument, *supra* note 115, at 88.

347. Attorney for the Prosecution in Transcript of Oral Argument, *supra* note 321, at 64–65.

348. *Id.* at 88.

349. An emerging scholarly literature explores the post-DNA meanings of “actual innocence” and “wrongful conviction” and considers the conceptual, strategic, and practical implications that follow. See generally Gross, *supra* note 139; Susan A. Bandes, *Framing Wrongful Convictions*, 2008 UTAH L. REV. 5 (2008); Richard A. Rosen, *Reflections on Innocence*, 2006 WIS. L. REV. 237 (2006); Carol S. Steiker & Jordan M. Steiker, *The Seduction of Innocence: The Attraction and Limitations of the Focus on Innocence in Capital Punishment Law and Advocacy*, 95 J. CRIM. L. & CRIMINOLOGY 587 (2005); Andrew M. Siegel, *Moving Down the Wedge of Injustice: A Proposal for a Third Generation of Wrongful Convictions Scholarship and Advocacy*, 42 AM. CRIM. L. REV. 1219 (2005); Margaret Raymond, *The Problem With Innocence*, 49 CLEV. ST. L. REV. 449 (2001).

350. *Edmunds*’s attorney emphasized this:

Yes, the DNA evidence can absolutely prove that somebody did not commit a crime and can absolutely prove somebody else did commit the crime, but that is not to say that that’s what you

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innocence is not the *sine qua non* of a new trial. But the subjectivity inherent in predicting the effect of new evidence on a jury's deliberations³⁵¹ means that the litigation of post-conviction relief motions will continue to take place in the shadow of DNA.

Given these formidable obstacles, the trial court's denial of Edmunds's motion³⁵² was to be expected. In the decision, we may rightly discern that similarly situated defendants will have difficulty prevailing in the future.³⁵³ Perhaps more surprising is that the trial court's decision was overturned on appeal.³⁵⁴ This development portends hope for those seeking new trials in SBS cases.

Even so, the promise of *Edmunds* is closely circumscribed by its limited precedential effect.³⁵⁵ Beyond onerous post-conviction relief standards,³⁵⁶ defendants seeking collateral relief in SBS cases confront the likelihood that, in coming years, the current scientific controversy will be suspended in a kind of equilibrium. At some point, unless a revolutionary breakthrough fatally undermines SBS, defendants convicted in this era of uncertainty will be hard-pressed to claim that evidence of the diagnosis's

have to have in order to create a reasonable probability of a different outcome. That's a real red herring here. That's a much higher standard than the clearly established legal standard under the case law.

Attorney for the Defense in Transcript of Oral Argument, *supra* note 115, at 135.

351. Daniel Medwed has observed generally that non-DNA cases are difficult for defendants to overturn . . . given the subjectivity involved in assessing most forms of new evidence and the absence of a method to prove innocence to a scientific certainty. This inherent difficulty in litigating innocence claims predicated on newly discovered non-DNA evidence is exacerbated by the structural design of most state post-conviction regimes

Medwed, *supra* note 318, at 658. Professor Medwed helpfully summarizes these collateral relief regimes. *Id.* at 681–86.

352. See *supra* notes 310–11 and accompanying text.

353. Edmunds was represented by Professor Keith Findley and the Wisconsin Innocence Project, a clinical program of the University of Wisconsin Law School whose mission is described at <http://www.law.wisc.edu/fjtr/clinical/ip/index.html>. It is worth noting that the Innocence Project, like others of its kind, has more resources, greater access to experts, and more extensive research capabilities than what is available to most defendants seeking post-conviction relief.

354. See *supra* notes 311–16 and accompanying text. Although he denied the defendant's motion, the trial judge's factual findings were particularly helpful to Edmunds on appeal. *Id.*

355. This is an inevitable feature of federalized system of justice. Where *Edmunds* is controlling, however, its impact may prove significant. See *Shaken-Baby Ruling Worries Prosecutor*, WIS. STATE J., Feb. 29, 2008, at C3 (“[A] prosecutor says it will be virtually impossible to convict anyone who shakes a baby to death in Wisconsin if a recent court ruling stands”).

356. One response to these realities is resort to a review commission, which may be the most efficient way of dealing with the systemic nature of triad-based SBS convictions and their potential failings. See *supra* notes 149–50 and accompanying text (describing approaches of United Kingdom and Canada).

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invalidity is new. Newly discovered evidence motions will be effectively foreclosed without ever having become truly viable.³⁵⁷

This prospect would be somewhat less problematic if, throughout the criminal process, a systemic assimilation of the evolved science was underway. As we have seen, however, it is not.

V. CONCLUSION

SBS is a case study in the intersection of science and law, and the distorting influence that each may have on the other.

The construction and persistence of SBS raises the distinct possibility that our adversarial system of criminal justice may be corrupting science. It may do so by placing pressure on scientists to articulate opinions more extreme—and certainly with more confidence—than those they actually hold.³⁵⁸ And it may do so by raising the stakes for those who have testified in court, under oath, to their version of scientific reality.

The natural course of scientific evolution has resolved many past medical conflicts. In the case of SBS, as well, ongoing research could ultimately answer the open questions.³⁵⁹ New technological developments

357. As the evolutionary trajectory of the science progresses and newly discovered evidence motions become obsolete, defendants whose trial lawyers failed to mount a substantial challenge to now-suspect medical orthodoxy will assert that their representation was ineffective. Keith Findley has articulated this point as follows:

where the medical evidence is 'new' in the ordinary sense—that is, the jury at trial never heard the medical evidence—but not new in the legal sense—it existed and could have been presented at trial—the defendant's claim will likely shift to a claim of ineffective assistance of counsel based on counsel's failure to marshal the available scientific evidence.

E-mail from Keith Findley, Clinical Professor and Co-Director, Wisconsin Innocence Project, University of Wisconsin Law School to Deborah Tuerkheimer, Professor, University of Maine School of Law (Dec. 10, 2008, 17:52) (on file with author).

358. One pediatrician with whom I spoke elaborated on this point:

the fact that we interact with lawyers and the court makes things worse. When you swear to tell the truth and nothing but the truth, are you swearing to speak only the truth, or to convey only the truth. Let's assume you believe you know the truth in the first place. You can only communicate in court through the artifices of the court by answering lawyers' questions that are purposely configured to structure and manipulate the truth. Within this venue, how do you deliver the "proper" concept into the minds of the jury, to whom you are trying to convey the truth. Some would assert that you should not reflect on uncertainties that you feel do not influence your ultimate opinion. You need to polarize your position, so that after cross and opposing witnesses, the jury lands in the middle where they belong.

This pediatrician, who asked not to be named, later added: "the urge to polarize your opinion significantly increase[s] when you are facing opposing 'expert' opinion, which you consider to be hyper-polarized, incompletely reflective of the clinical case, scientifically incorrect or outright disingenuous."

359. My conversations with advocates on both sides of this debate can be generalized as follows. Those who believe that SBS is an invalid diagnosis cite ongoing research into the previously

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would facilitate this process. But SBS, from inception to current iteration, is fully embedded in the domain of law. This reality creates a special kind of urgency: around the country, murder convictions are resulting weekly from evidence that is a source of significant scientific controversy. Even if it were possible for research to progress on this front “naturally”—a dubious proposition given what has come before³⁶⁰—organic processes take time, which, here, is of the essence.

Even more untenable is the suggestion that this scientific dispute be decided in the courts. As the cautionary tale of SBS demonstrates, our adversarial, atomized system of justice, with its need for finality, is a poor forum for this debate. The institutional norms of science and law often collide; in this case, with tragic results. Without proper differentiation of their respective functions, both scientific certainty and individualized justice suffer.

To the greatest extent possible, then, a comprehensive inquiry must take place apart from the fray.³⁶¹ Perhaps only the National Academy of Sciences (NAS)³⁶²—or, even more fittingly, a similar undertaking by a newly created National Institute of Forensic Sciences³⁶³—can provide this space.

undetected prevalence of retinal hemorrhages (by Patrick Lantz, among others) and subdural hemorrhages (by Ronnie Rooks, among others) as critical to resolving the debate. Defenders of the diagnosis point to better modeling and the possibility of capturing a shaking episode on film as the impetus for resolution. *But see*, <http://www.youtube.com/watch?v=jBsXA4H5Dzw> (last visited July 23, 2009) (shaking of an infant recorded on a “nanny-cam,” baby was not injured). Of course if, in the future, shaking resulting in the classic SBS symptoms is recorded on video, this may tend to establish that shaking alone can cause the triad, but it will not prove a pathognomic relationship between shaking and the triad. Put differently, proof that A can cause B does not equate with proof that B is necessarily caused by A.

360. *See supra* Part III.A.

361. Others within the scientific community have been agitating for a neutral body to undertake a thorough study of the basis for SBS. *See, e.g.*, Bohan, *supra* note 76 (calling this “long past the time that persons capable of scientifically examining [the controversy surrounding the diagnosis] be called on to do so as part of an independent broad-based team under the auspices of the National Academies of Science.” Interview with Thomas Bohan, *supra* note 78. Even outside the SBS context, one commentator has recently argued that greater “institutionalized oversight of forensic sciences, by scientists, is needed to compensate for the inadequacies of adversary adjudication.” Keith A. Findley, *Innocents at Risk: Adversary Imbalance, Forensic Science, and the Search for Truth*, 38 SETON HALL L. REV. 893, 955 (2008).

362. According to its own assessment, “[t]he reports of the National Academies are viewed as being valuable and credible because of the Institution’s reputation for providing independent, objective, and non-partisan advice with high standards of scientific and technical quality.” From National Academies: Our Study Process, <http://www.nationalacademies.org/studycommitteeprocess.pdf> (last visited July 23, 2009). Within the scientific community, this seems to be a generally accepted characterization. A NAS study requires a federal agency as its primary financial sponsor, implicating the willingness of Congress to authorize funds for the endeavor. *Id.*

363. In February 2009, the National Research Council of the National Academies issued its much heralded report, *Strengthening Forensic Science in the United States: A Path Forward*, available at

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In the meantime, until scientific consensus has been achieved, the criminal justice system must find its own solutions to the problem of a diagnosis already morphed and still in transition.

To date, our system has failed. In place of adaptation, we have seen massive institutional inertia. Once the SBS prosecution paradigm became entrenched, the crime became reified. Deferential review standards and a quest for finality perpetuated the system's course. How expeditiously, and how deliberately, this course is righted will inform the meaning of justice.³⁶⁴

Complicating the endeavor, SBS prosecutions raise discomfiting possibilities that diverge from those presented by the innocence archetype. Here, no other perpetrator can be held accountable; indeed, no crime at all may have occurred. The problem is not individual, but systemic, and its source is error, not corruption. Responsibility is diffuse: prosecutors and scientists may each legitimately point fingers. Most fundamentally, scientific developments have cast new doubt without yet creating certainty in its place. The story of SBS thus challenges current notions of wrongful convictions. Underlying conceptual frameworks must evolve accordingly.

For now, we find ourselves situated in an extraordinary moment; one which tests our commitment to innocence that is not proven, but presumed.

http://www.nap.edu/catalog.php?record_id=12589 (last visited July 23, 2009). Although the NRC Report did not specifically address the problem of SBS, it did catalogue a wide range of ways in which "substantive information and testimony based on faulty forensic science analyses may have contributed to wrongful convictions of innocent people." *Id.* at S-3. Perhaps most importantly, the Report recommended creation of a new independent federal agency, the National Institute of Forensic Science (NIFS), whose mission would encompass "establishing and enforcing best practices for forensic science professionals;" "developing a strategy to improve forensic science research and educational programs, including forensic pathology;" and "promoting scholarly, competitive peer-reviewed research . . . in the forensic science disciplines and forensic medicine." *Id.* at S-14.

364. I pursue the question of reform in a future Article.

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Shaken Baby Syndrome: Debunking the Myth

The problem isn't with what we don't know. The problem is with what we do know that isn't so.

-Will Rogers

In 1997 the world held its breath as the media followed closely Louise Woodward's "nanny" trial. She had allegedly committed the crime of shaking a baby, which resulted in the death of infant Matthew Eappen. Miss Woodward was a 19-year-old British au pair with no criminal record, yet she was "disliked" by the camera and as is often the case in crimes involving children, was presumed guilty.

Prosecutors maintained Woodward was frustrated and angry with the baby's parents who objected to her late nights out past curfew. In retaliation, it is speculated Woodward violently shook and then slammed the baby's head against a hard surface, causing the massive brain damage that led to his death five days later at Children's Hospital in Boston.

Accompanied by a host of experts, attorneys and UK supporters via satellite, Woodward was convicted to life with the possibility of parole after 15 years when a jury decided no "reasonable" person would have done what she was accused of doing to baby Matty (Bowker).

Both the prosecution and defense had presented respected expert witnesses who disagreed on the evidence. Judge Hiller Zobel found that the jury had found her guilty of a second-degree murder without being allowed to consider a manslaughter verdict and that there was much reasonable doubt in this case. He then vacated the verdict, convicted Woodward with manslaughter and gave her a time served sentence (Zobel).

Even a seasoned judge felt there is not much validity in the prosecution's argument. So, if Shaken Baby Syndrome, (SBS), is a diagnosis full of disagreement and doubt, then SBS should be considered "junk science" because SBS is based on theory and cannot be proven, a time of injury cannot be isolated and there may be alternate causes for the injuries.

SBS originated over 30 years ago.

John Caffey, an American pediatric neurologist and radiologist, coined the diagnosis theory of SBS in 1972. Shaken Baby Syndrome (SBS) is a popular diagnosis given over the last 30 years when a child has internal injuries that cannot be explained from obvious accidental injury.

The "whiplash shaken infant syndrome" is a result of manual shaking by the extremities with whiplash-induced intracranial and retinal bleedings, linked with permanent brain damage or death. He came to this conclusion when a nurse who worked in a neonatal unit admitted that she had shaken infants to stop them from crying and many of those infants were found to have had head injuries, (Caffey 161).

There is reason for an inference here, but certainly not a scientific basis on which to convict caretakers for murder when the stories are inconsistent with the history provided. No one can prove the theory because it is obviously unethical to shake a baby.

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Although there have been many confessions, it is not abnormal for a caregiver to find a child unconscious, panic and shake them to illicit a response and then feel that surely the doctors and police know what they are doing; thus assuming that responsibility lies within themselves.

Brian J. Clark, a consultant pathologist from the UK contends,

"No reasonable professional of any discipline wants to see malicious child homicide go undetected and unpunished. However, it is equally abhorrent over-zealous investigation, refusal to study alternative explanations, or narrow-minded pursuit of blame for an infant's death (that) can destroy the lives of the accused and their family, creating supplementary victims. This is particularly salient when the accused and the families of the accused are recently bereaved relatives of the deceased child. We have an inescapable duty to get this right!" (415).

There is much debate within the medical community, particularly forensic pathologists, as to the time of injury. This presents a huge problem to the enthusiastic law enforcement so eager to make an arrest in what is presumably SBS.

The majority of professionals contend that an injury severe enough to produce death must have occurred immediately before symptoms' onset and that the responsible party must have been the last caregiver who is often alone with the child.

However, as there has been little research to validate this assumption, many are coming forward to debate this evidence, (or lack of), by disputing that there may be a lucid stage in which the child, lacking obvious external injury, appears to an unknowing public as being fine.

Upon accusation, the parties may realize that a baby was fussy, lethargic or "not himself" when it is too late to validate with physicians. The 'lucid interval' has been accounted to actually last from 5 minutes to 3 days and has been proven in studies when many parties or even video has evidence of an accidental head injury, such as a fall from playground equipment.

John Plunkett, a pediatric forensic pathologist has done studies specifically involving children who fall observed from short distances and suffer injuries as serious as a subdural hematoma and retinal hemorrhages, the hallmark signs of SBS.

Other than a non-accidental, inflicted injury, these damages had formerly been attributed only to falls from a two-story building or a high-speed vehicle accident. However, there has never been any study to determine a minimum force to cause lethal injury.

"Many physicians believe that a lucid interval in an untimely fatal pediatric head injury is extremely unlikely or does not occur unless there is an epidural hematoma. Twelve children in this study had a (observed) lucid interval. A non-caretaker witnessed 9 of these 12 falls. One child had an epidural hematoma" (9).

So, a lucid interval is always possible and a tragic accident, such as a fall may also be to blame. Plunkett concludes: "A fall from less than 3 meters in an infant or child may cause fatal head injury and may not cause immediate symptoms. The injury may be associated with bilateral retinal hemorrhage, and an associated subdural hematoma may extend into the interhemispheric fissure. A history by the caretaker that the child may have fallen cannot be dismissed" (10).

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Also, there is debate as to whether a previous injury from birth or an overlooked fall, etc. may have first injured the child and a rebleed when something minor happens may cause the tender tissue to rupture. This would be a prime understanding for a chronic subdural in which a child is supposedly abused over a long period of time.

However, no one really knows what may cause a rebleed because there hasn't been much research on it.

Harold Buttram, a physician who studies SBS, has written,

"It has been demonstrated that the neomembrane surrounding an organizing subdural hematoma may itself bleed, and that expansion of a subacute/chronic subdural hemorrhage may cause new bridging veins to rupture, and that an acute clot may predispose to new bleeding. New bleeding in an established subdural hematoma may occur spontaneously and without new trauma. In the cited example, the child was in a hospital under the care of a physician." (84).

Despite popular belief that vaccines are required for a child to attend school, all 50 states allow for a religious and/or philosophical exemption. When a child is vaccinated, a pediatrician must have the parental signature before he may proceed because it is known that adverse reactions, even death may result.

If parents were aware of the toxic ingredients and devastating consequences of vaccines, perhaps they would choose not to immunize.

Vera Scheibner, an Australian physician and researcher has written extensively on vaccine damage.

"One only has to peruse a product insert of hepatitis B vaccine to see that besides local reactions, a number of neurological signs may occur, such as paraesthesia and paralysis (including Guillain-Barre syndrome, optic neuritis and multiple sclerosis)" (82).

Also, a group of Japanese physicians did research on pertussis vaccine and determined it to cause brain swelling.

"Indeed, vaccines like the pertussis (whooping cough) vaccine are actually used to induce encephalomyelitis (experimental allergic encephalomyelitis) in laboratory animals. This is characterized by brain swelling and haemorrhaging of an extent similar to that caused by mechanical injuries" (Iwasa et al. 56).

In Japan, children are no longer immunized for pertussis due to the local medical community's outrage.

In many cases of SBS, the symptoms occur following routine vaccinations. The child may cry intensely and inconsolably, may stop feeding properly, vomit, have difficulty swallowing, become irritable, stop sleeping, and may develop convulsions with accelerating progressive deterioration of its condition and mainly its brain function (Scheibner 82).

Adverse reactions to vaccines do not have to occur immediately as many pediatricians will tell a parent. They have been noted to take up to 14 days. If a parent shows concern that his child is

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behaving oddly, a pediatrician or emergency room tells him that it is a normal reaction, give the child infant Tylenol and within time the symptoms will cease.

If he persists in considering the baby's reaction abnormal, he is called worrisome. Sadly, by the time the parent second guesses the physician(s), the damage is often irreversible and the child may be found comatose or deceased.

It has already been mentioned that infant Tylenol is encouraged when a child has a fever or is "fussy" following vaccinations. Although there have not been thorough studies done to assess the damages, a parent should use extreme caution when dispensing such medicine as an overdose may cause severe damage as acetaminophen alters blood viscosity and could trigger or further intercranial pressure.

In addition to vaccines, there are other plausible definitions for what may mimic SBS.

Glutaric aciduria, also called glutaric acidemia, is a rare inherited metabolic disorder. There are two types, 1 and 2. The symptoms of type 1 are remarkably similar to those seen in shaken baby syndrome and often include subdural hematoma and retinal hemorrhage

Scurvy (in infants known as Barlow's disease), may also explain subdural hemorrhage, bruising and broken bones that can further be a red flag to abuse. Archie Kalokerinos, a physician in Australia, submits that scurvy is more prevalent at an earlier age than 75-100 years ago due to administration of antibiotics, administration of vaccines, failure to exclusively breastfeed and the role played by endotoxins.

Scurvy is a disease caused by vitamin C deficiency that affects collagen formation. Poor collagen formation can damage tissue, blood vessels and bone which can lead to bruising and hemorrhages anywhere on the body. This includes subdural hemorrhages, retinal hemorrhages and fractures.

Further, if an infant receives vitamin C supplements that outweigh the recommended daily dose, he may also develop scurvy! (Kalokerinos).

Oxygen deprivation (hypoxia) can be caused by choking, asphyxia, or infection and causes a lack of oxygen identifiable in the blood and swells the brain, causing a respiratory arrest, which then illicit bleeding.

A reporter for The Times newspaper in London recently wrote an article entitled "Junk Science: Shaken Baby Syndrome" in which he has discovered that-

"among one sample of babies who were classified as victims of SBS, more than half showed evidence of a lack of oxygen in the blood. This could have caused the brain to swell and cause bleeding as a secondary symptom" (Ahuja,). Other conditions that may induce symptoms which mimic SBS include but are not limited to hemophilia, coagulopathies, hydrocephalus, Thrombocytopenia (TCP), Thrombocythemia, Von Willebrands Disease (VWD), Waldenstrom's Macroglobulinemia, Multiple Myelomas, Cryoglobulinemia, sepsis and certain antibiotics may increase endotoxins.

If a case is misdiagnosed as child abuse, the child is denied proper attention and it is not known how many caretakers may have been falsely accused and prosecuted.

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One has simply to reflect on the historical reference of the Salem witch trials of 1692 to comprehend that a theory can become overblown.

In the 1980's, there was an epidemic where innumerable childcare workers were arrested on allegations of ritualistic sexual abuse. Respectable men and women who so loved children lost their livelihood and reputations spending tens of thousands of dollars on a criminal defense before it was recognized that many of the children had been prompted to accuse their caregivers. Although many were vindicated, others spent lengthy time incarcerated and cannot replace lost years.

It is possible that infanticide and child abuse are involved in some of the alleged SBS cases. However, law enforcement has given no justification as to why, within the past 30 years, thousands of caregivers and parents have suddenly decided to shake their beloved infants for whatever reason is presented as motive to a jury.

It is incredibly callous to accuse a grief-stricken parent or loved one of harming a child when all avenues for explanation have not been explored by an ignorant or uninformed coroner.

British neurologist, JF Geddes, wrote a controversial article in the British Medical Journal in March of 2004. Titled, "The Evidence Base for Shaken Baby Syndrome", she questions the diagnosis.

"If the issues are much less certain than we have been taught to believe, then to admit uncertainty sometimes would be appropriate for experts. Doing so may make prosecution more difficult, but a natural desire to protect children should not lead anyone to proffer opinions unsupported by good quality science. We need to reconsider the diagnostic criteria, if not the existence, of shaken baby syndrome" (720).

There are so many alternate causes, timing of injury cannot be isolated and research on theory is lacking.

SBS should be considered "junk science" until further technology can prove that it is a viable diagnosis.

Sabrina Nedrow

Sabrina Nedrow is a mother falsely accused of SBS and is fighting for her children for four years with SCDSS while being denied a criminal trial.

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NO. F04-49745-L

THE STATE OF TEXAS

VS.

MARIA ISABEL HURTADO

§
§
§
§
§

IN THE CRIMINAL DISTRICT

COURT NUMBER FIVE

DALLAS COUNTY, TEXAS

FILED

2006 FEB 17 AM 6:27

DISTRICT CLERK
DALLAS COUNTY, TEXAS
DEPUTY

**DEFENDANT'S MOTION TO EXCLUDE EXPERT TESTIMONY
PURSUANT TO TEXAS RULE OF EVIDENCE 702**

TO THE HONORABLE JUDGE OF SAID COURT:

NOW COMES the defendant, MARIA ISABEL HURTADO, and submits this motion to exclude expert testimony pursuant to Texas Rule of Evidence 702. Defendant requests that the Court hold a hearing on this motion, and thereafter strike the state's proposed expert testimony on shaken baby syndrome.

Issue Presented

Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993) and *Kelly v. State*, 824 S.W.2d 568 (Tex. Crim. App. 1992) require trial courts to function as gatekeepers, shielding the jury from expert opinion testimony that has not been shown, by *clear and convincing evidence*, to be scientifically reliable. The question in this case is whether shaken baby syndrome expert opinion testimony meets this high standard when the defendant presents a significant amount of reliable scientific evidence invalidating the theory and the State fails to fully explain its flaws and inconsistencies.

The Development of a Reliability Standard

For many years, the standard for the admissibility of expert opinion testimony required

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only that the testimony be generally accepted in the relevant scientific community.¹ The *Frye* standard, as it was known, was applied in federal courts as well as in most states. However, after Congress put its imprimatur on the Federal Rules of Evidence, Rule 702 governed the admissibility of expert testimony. Texas also adopted Rules of Evidence modeled largely on the Federal Rules. Texas Rule of Evidence 702 provides:

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise.

Although Federal Rule 702, as well as the Texas Rule, set out a seemingly different standard for admissibility than *Frye*, the courts continued to rely on the *Frye* standard when assessing challenges to expert opinion testimony.²

The Supreme Court responded to the lower courts' application of Rule 702 in *Daubert v. Merrell Dow Pharmaceuticals*.³ The Court replaced the *Frye* standard with a reliability standard. No longer did the trial court function merely as a referee, weighing the amount of acceptance a theory had gained in the relevant community, the trial court became the gatekeeper, making an independent assessment of the theory's reliability and the reliability of the methods used in applying the theory.⁴ The Court emphasized that trial courts should assess reliability based on the scientific method.⁵ And the Court provided four factors to

¹*Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923).

²*Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 585 (1993)

³*Id.* at 587-89.

⁴*See id.* at 592-93.

⁵*Id.* at 590.

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guide lower courts in weighing the scientific reliability of expert testimony:

- (1) the extent of empirical testing;
- (2) the level of scrutiny and public testing in the scientific community;
- (3) consideration of the known or potential rates of error; and
- (4) a determination of the degree of acceptance within the relevant scientific community.⁶

Daubert cleared the way for novel science in the courtroom. Where a novel theory has not yet gained general acceptance in the relevant community, the proponent of novel scientific evidence can present testimony to the jury if the court finds the scientific theory sufficiently reliable. On the other hand, scientific expert theory that has gained wide acceptance in the community does not automatically make it to the jury, not even when the scientific theory is overwhelmingly accepted. Each theory offered by an expert requires an independent reliability assessment.

Since the Supreme Court's watershed opinion in *Daubert*, trial courts have acted as stringent gatekeepers, keeping unreliable scientific expert testimony away from the jury – primarily in civil trials.⁷ Most states, including Texas, apply a variation of the *Daubert*

⁶*Id.* at 593-594.

⁷Paul Gianelli, *The Supreme Court's "Criminal" Daubert Cases*, 33 Seton Hall L. Rev. 1071, 1072 (2003); *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 43 F.3d 1311 (9th Cir. 1995) (on remand) (emphasizing importance of scientific evidence being based on research); *Clair v. Burlington Northern Railroad*, 29 F.3d 499 (9th Cir. 1994) (upholding exclusion of expert testimony regarding exposure to chemicals in work place); *O'Conner v. Commonwealth Edison*, 13 F.3d 1090 (7th Cir. 1994) (upholding exclusion of physician's expert opinion that he could tell whether particular cataract was caused by radiation); *Casey v. Ohio Medical Products*, 877 F.Supp. 1380 (N.D. Calif. 1995) (opinion of witness based on case studies was not based on reliable scientific evidence and was not admissible under *Daubert*); *Smoltz v. Norfolk and Western Ry. Co.*, 878 F.Supp. 1119 (N.D. Ill. 1998) (plaintiff's expert did not come forward with sufficient empirical support for causation opinion that condition was caused by

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standard in criminal trials as well. And, when assessing whether to allow scientific expert opinion before a jury in a criminal trial, criminal trial courts must grapple not only with the reliability of the scientific principles, but must do so in the context of a system which gives criminal defendants more protections than civil litigants.

The Greater Importance of Reliability in the Criminal Context

Our legal system reflects our societal values. Those values afford criminal defendants more protections because at stake in a criminal trial is someone's life or liberty. In a civil action, usually only one's money is at risk. Also our constitution mandates that we assume a person's innocence until proven guilty.⁸ Therefore, we require plaintiffs in a civil action to prove their case merely by a preponderance of the evidence. Whereas, in a criminal trial the State must prove the defendant guilty beyond a reasonable doubt. Criminal defendants are afforded court appointed counsel; civil litigants are not.⁹ Criminal defendants also enjoy, among other rights, a constitutional right to confront their accusers.¹⁰ Nowhere, then, is the gatekeeping function more important than in the context of the criminal trial.

The trial court should remain cognizant of the additional duty placed upon it in criminal trials – that of protecting a defendant's constitutional rights – because all the rights

exposure to herbicides); *Porter v. Whitehall Laboratories, Inc.*, 9 F.3d 607 (7th Cir. 1993) (finding experts testimony inadmissible because it was not well grounded in the scientific method); *Rosen v. Ciba-Gelgy Grp.*, 78 F.3d 316 (7th Cir. 1996) (testimony of physician serving as expert witness for smoker that patch had caused heart attack was not valid scientific evidence and was not admissible under *Daubert*); *Moore v. Ashland Chemical, Inc.*, 151 F.3d 269 (5th Cir. 1998) (upholding exclusion of expert testimony not scientifically based).

⁸See U. S. Const. amend. V.

⁹U.S. Const. amend VI.

¹⁰*Id.*

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afforded criminal defendants can be eviscerated by a failure in the gatekeeping function. For example, Justice Blackmun, the author of the *Daubert* opinion, argued in a pre-*Daubert* case that the introduction of unreliable expert testimony violated the defendant's due process rights. Justice Blackmun, dissenting in *Barefoot v. Estelle*, argued:

The Court holds that psychiatric testimony about a defendant's future dangerousness is admissible, despite the fact that such testimony is wrong two times out of three. The Court reaches this result – even in a capital case – because, it is said, the testimony is subject to cross-examination and impeachment. In the present state of psychiatric knowledge, this is too much for me. One may accept this in a routine lawsuit for money damages, but when a person's life is at stake – no matter how heinous his offense – a requirement of greater reliability should prevail. In a capital case, the specious testimony of a psychiatrist, colored in the eyes of an impressionable jury by the inevitable untouchability of a medical specialist's words, equates with death itself.¹¹

As Justice Blackmun pointed out, when experts are allowed to express their opinions before a jury without stringent gatekeeping, defendants are bound to lose. Nowhere is this truer than in shaken baby syndrome cases. Courts may be tempted to take the position that the parties' experts can battle it out in front of the jury. But this kind of battle, without proper reliability vetting, is destined to doom the defendant's case. First, juries are generally not equipped to serve as the arbiters of scientific reliability. This is particularly true in Shaken Baby Syndrome cases where equally qualified doctors come to diametrically opposite conclusions. Second, often the least scientific and hence least reliable of expert testimony is the most persuasive testimony. For example, an expert who testifies about DNA profiling must give potential error rates. The DNA expert may tell the jury that there is a one in one million chance that another human could match the same DNA profile. On the other hand,

¹¹463 U.S. 880, 916 (1983).

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an expert who testifies that the science is exact, that there is no error rate, tends to make a much stronger impression on the jury. Finally, in shaken baby cases specifically, the State's experts tend to be pediatricians and other doctors who work in child abuse clinics. Although this makes them no more or less an expert on the shaken baby syndrome, the jury may see them as having greater reliability because of their position. When the defense calls an expert with excellent credentials, those credentials can be overshadowed by the fact that the expert was "hired" by the defendant. The jury, therefore, may likely conclude that the defendant's experts have a specific agenda – that of ensuring that the defendant goes free. Because juries will tend to overvalue the State's experts and undervalue the defendant's experts, a failure in stringent gatekeeping will tend to unduly prejudice criminal defendants. Failure to stringently exercise the gatekeeping function in a criminal trial not only threatens a defendant's right to due process, it may also deny a defendant of the right of confrontation.¹² When experts give opinions in a criminal trial that inculpate the defendant, the defendant maintains the right to cross-examine not just the expert's opinions, but the basis of the opinions. Expert opinions are hearsay evidence, specifically allowed in a trial under Rule 702. But when an expert testifies against a criminal defendant and cannot provide the studies and methodologies that give rise to the expressed opinions, the defense is unable to confront the hearsay evidence against the defendant – that is, the particular hypotheses that form the scientific theory espoused by the expert. Therefore, when experts offer their opinions without providing the basis for the opinions, they shield the basis of that opinion from cross-

¹²See Gianelli, *supra* note 7, at 1083-86.

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examination and violate a defendant's constitutional right of confrontation.¹³

Finally, in shaken baby syndrome cases, allowing an expert opinion that relies on the defendant to prove the theory wrong, unconstitutionally shifts the burden of proof to the defendant. For example, experts define shaken baby syndrome as the presence of a subdural hematoma and retinal hemorrhages in an infant without a sufficient historical explanation for the injuries.¹⁴ When the syndrome is defined in those terms, the expert sets up a scenario in which the defendant must credibly explain what caused the injuries because the definition itself requires it. If the defendant fails to give an explanation that satisfies the expert or gives no explanation at all, the expert concludes that the child's injuries emanated from non-accidental causes, specifically, shaking. Allowing expert testimony that puts before the jury a diagnosis that *by definition* relies on the defendant to disprove the diagnosis, unconstitutionally shifts the burden to the defendant in a criminal trial.

Reliability Requirements in Texas Courts

Texas courts have adopted the *Daubert* approach in near identical fashion to that utilized in federal courts.¹⁵ The Texas Court of Criminal Appeals and Texas Supreme Court have developed factors, commonly known as the *Daubert/Robinson/Kelly* factors, that trial courts should use to assess an expert opinion's reliability. Among them are:

- (1) the extent to which the underlying scientific theory has been or can be tested;

¹³See *Crawford v. Washington*, 541 U.S. 36 (2004) (prohibiting the admission of testimonial hearsay in criminal trials).

¹⁴Testimony of Dr. Matthew Cox.

¹⁵*Russeau v. State*, 171 S.W.3d 871, 881 (Tex. Crim. App. 2005); *E.I. du Pont de Nemours & Co. v. Robinson*, 923 S.W.2d 549, 557 (Tex. 1995).

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(2) the extent to which the technique or theory relies on the subjective interpretation of the expert;

(3) the existence of literature supporting or rejecting the underlying scientific theory and technique;

(4) the technique's potential error rate;

(5) whether the underlying theory or technique has been generally accepted as valid by the relevant scientific community; and

(6) the non-judicial uses which have been made of the theory or technique.¹⁶

Further, and most importantly, in Texas criminal trials "[t]he proponent of scientific evidence must demonstrate to the trial court, *by clear and convincing evidence*, that the scientific evidence is reliable"¹⁷ and that the expert witness truly has expertise in the precise area in which he is testifying.¹⁸

Therefore, the issue now before this Court is whether the State can demonstrate through a qualified witness, *by clear and convincing evidence*, that the theory of shaken baby syndrome is scientifically reliable. In considering the ultimate issue before the Court, Defendant offers several questions:

¹⁶See *Russeau*, 171 S.W.3d at 881; *Robinson*, 923 S.W.2d at 557; *Kelly v. State*, 824 S.W.2d 568, 572 (Tex. Crim. App. 1992); *Hartman v. State*, 946 S.W.2d 60, 62, 63 (Tex. Crim. App. 1997).

¹⁷*Russeau*, 171 S.W.3d at 881(emphasis added); *see also Kelly*, 824 S.W.2d at 573.

¹⁸See, *Gammill v. Jack Williams Chevrolet, Inc.*, 972 S.W.2d 713 (Tex. 1998); *Henderson v. State*, 77 S.W.3d 321 (Tex. App. - Fort Worth 2002) (both cases holding that the expert must truly have expertise in the area in which they are offering an opinion).

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I. If shaken baby syndrome is a reliable scientific theory, then why is there no consistent definition?

In 1972, John Caffey, a pediatric radiologist first termed what is now identified as shaken baby syndrome, as “whiplash shaken baby syndrome.”¹⁹ In Caffrey’s study, he argued that shaking alone could cause serious brain injury, but he also concluded that a caretaker could cause these injuries innocently – by tossing the baby in the air or burping the baby.²⁰

Shaken baby syndrome has also been defined as a constellation of clinical findings in infants, which include retinal hemorrhages, subdural and/or subarachnoid hemorrhages, *and little or no evidence of cranial trauma*. State’s experts have defined SBS as evidenced by subdural hematoma, retinal hemorrhage and an inadequate explanation for their occurrence.

So the definition morphed from possible benign shaking causing a whiplash effect – to the existence of a subdural hematoma and retinal hemorrhages and no cranial trauma – to a subdural hematoma and retinal hemorrhages and no adequate explanation for the mechanism of injury.

Now consider that many experts do not agree that shaking alone can cause the injuries commonly described as shaken baby syndrome. In fact, shaken baby syndrome, for some, has morphed into shaken impact syndrome. Even now, some state’s experts will contend the injury can be caused by shaking alone and others will say that impact is required.

¹⁹John Caffey, *The Whiplash Shaken Infant Syndrome: Manual Shaking by the Extremities with Whiplash-Induced Intracranial and Intraocular Bleedings, Linked with Residual Permanent Brain Damage and Mental Retardation*, 54 Pediatrics 396 (1974).

²⁰*Id.*

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Finally, at least seven experts have suggested that instead of using the term shaken baby syndrome, which automatically implicates physical violence, physicians should use a descriptive term such as “‘infantile encephalopathy with subdural and retinal bleeding,’ which has no aetiological implications.”²¹ This suggestion takes into account the reality that an infant can suffer a subdural hematoma and retinal hemorrhages from accidental or other disease related causes.

With such a variance in the way the shaken baby syndrome or the shaken impact syndrome has been defined, it is important at the outset that the Court and the defendant know what definition each expert is using when referring to the theory. Without a precise definition of the theory, the theory is beyond the reach of reliability testing.

II. If shaken baby syndrome is a reliable scientific theory, then why did an evaluation of the supporting medical evidence of shaken baby syndrome find that evidence “inadequate to support *any* standard case definitions or *any* standards for diagnosis assessment”?

Recently, members of the medical profession have demanded the best available medical and scientific evidence to reach a medical opinion or diagnosis; this approach is known as “evidence-based medicine (EBM) and involves a review of the quality of evidence that is available in various diseases and fields of inquiry in medicine.”²² Using the standards of EBM, Mark Donohoe evaluated and ranked the “available medical evidence by internationally accepted methods, to determine the degree of confidence that can be held on

²¹JF Geddes, et al., Dual Hemorrhage in Non-Traumatic Infant Deaths: Does It Explain the Bleeding in “Shaken Baby Syndrome”?, 29(1) Neuropathology & Applied Neurobiology 14-22 (2003).

²²Mark Donohoe, *Evidence-Based Medicine and Shaken Baby Syndrome: Part I: Literature Review, 1966-1998*, 24(3) Am. J. Forensic Medicine and Pathology 239-42, 239 (2003).

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various claims about the condition termed shaken baby syndrome.”²³

The review took no position on what the diagnostic criteria should be, rather it merely aimed to evaluate the current case studies relied upon in the literature to reach the hypotheses and diagnoses. The review ranked the research from I to IV, with I having the highest Quality of Evidence Rating (QER) and IV having the lowest QER. The review found and evaluated 54 articles or abstracts on the topic of shaken baby syndrome, only one of which was a randomized controlled trial. However, this article was not relevant to the general topic of shaken baby syndrome and only dealt with the matter peripherally. The other articles included 26 case series and 25 retrospective studies. Only one article was based on a prospective study.²⁴

The evaluation found “[m]any studies lacking these critical data [direct or undisputed evidence of the occurrence, severity, or type of trauma] make the obvious logical error of selecting cases by the presence of the very clinical findings and test results they seek to validate as diagnostic. Not surprisingly, such studies tend to find their own selection criteria pathognomic [or diagnostic] of [shaken baby syndrome].”²⁵

The evaluation concluded that “[t]here was no evidence on the subject of [shaken baby syndrome] that exceeded QER III-2 . . . which means that there was inadequate scientific evidence to come to a firm conclusion on most aspects of causation, diagnosis,

²³*Id.*

²⁴*Id.* at 240.

²⁵*Id.* at 239.

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treatment, or any other matters pertaining to [shaken baby syndrome].”²⁶ The vast majority of the evidence received a level of QER IV, the lowest possible rating. In fact, “[m]any of the authors repeated the logical flaw that if [retinal hemorrhaging and subdural hematoma are nearly always seen with [shaken baby syndrome], the presence of [retinal hemorrhaging and subdural hematoma] ‘prove’ that a baby was shaken intentionally.”²⁷ The remaining data collected was QER III-3 and included no controls. Using Evidence Based Medicine, with QER criteria for evaluating evidence, the ultimate result was that the evidence was “inadequate to support *any* standard case definitions, or *any* standards for diagnosis assessment.”²⁸

One of the factors a court should consider when deciding whether to admit expert testimony under Rule 702 is whether the theory has been subjected to peer review or publication. Dr. Donohoe’s evaluation of shaken baby syndrome confirms that the theory has been subjected to peer review and publication. The evidence-based-medicine evaluation further concludes that the best evidence available in the publications on shaken baby syndrome fail to support the theory. A theory that cannot convince the relevant medical community of its reliability has no place in a courtroom where the burden on the proponent of the theory is to demonstrate its reliability by clear and convincing evidence.

²⁶*Id.* at 241.

²⁷*Id.*

²⁸*Id.*

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III. If shaken baby syndrome is a reliable scientific theory, then why does it rely on a layperson's subjective explanation of the mechanism of injury and the subjective interpretation of the expert?

Texas precedent suggests that the trial court consider the extent to which the proffered scientific theory relies upon the subjective determination of the expert when deciding whether the expert testimony is sufficiently reliable under Rule 702.²⁹ Shaken baby syndrome, however, relies not just on the subjective interpretation of the expert, but on the subjective explanations of lay people acting as caregivers to the child.

Shaken baby syndrome, by most definitions, requires not only the presence of a specific injury – subdural hematoma coupled with retinal hemorrhages – but a caregiver's story that fails to explain the mechanism of the injury.³⁰ In fact, "the key to diagnosis is a significant disparity between the suggested mechanism of injury and the actual injuries observed."³¹ Using the opinions of a parent or caretaker as a dispositive diagnostic criteria is counter-intuitive at best and is not science. No other medical diagnosis relies so heavily on subjective criteria that has no relationship to medical expertise. Caretakers with no medical training who may not have been present during any accidental or non-accidental trauma are placed in an impossible situation, required to explain the cause of injury. Science, however, does not rely completely on the explanations of outsiders to determine causation – hypotheses regarding causation are derived through observation and *experimentation*.

Further destroying the scientific nature of shaken baby syndrome, proponents of the

²⁹*E.I. du Pont*, 923 S.W.2d at 557.

³⁰Testimony of Dr. Matthew Cox.

³¹*Lancon*, *supra* note 24 at 14.

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syndrome subjectively alter the facts rather than the hypothesis when confronted with a caretaker's explanation of injury. For example, when caretakers "confess" that they shook the baby after it stopped breathing, the experts are willing to believe the caretakers, at least the part of the statements admitting to shaking, but are unwilling to believe the caretakers' explanation of the timing of the shaking, suggesting that the caretakers shook the baby before it stopped breathing rather than after. Experts selectively sift through pieces of the caretakers' explanations to gather evidence to support their own hypothesis.³²

One retrospective clinical study³³ conducted by shaken baby syndrome proponent, David Chadwick, exemplifies the subjective lens through which these cases are viewed. The study focuses on 283 children who suffered head injuries from falls. Of these 283 children, 100 reportedly fell from a distance of no more than 4 feet; 183 of them fell from heights of between 10 and 45 feet. Of the short distance falls, 7 children died of head injury. All of the seven had subdural bleeding and cerebral edema, and one of the seven suffered a fractured skull. Of the falls from greater heights, only one child died from the injuries. The statistics showed that the likelihood a child would die from a short distance fall was eight times greater than a fall from heights of 10 to 45 feet.³⁴ Instead of concluding that short distance falls can cause serious head injury, instead of investigating the way a child's head might react in short falls versus falls from greater heights, instead of concluding that the control group was not

³²See Brian Clark, *Retinal Hemorrhages: Evidence of Abuse or Abuse of Evidence?*, 22(4) Am. J. of Forensic Medicine and Pathology 415-16 (2001).

³³David Chadwick, et al., *Deaths from Falls in Children: How Far Is Fatal?*, 31 J. Trauma 1355 (1991).

³⁴*Id.*

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sufficient in number to convey accurate statistical data, the experts conducting the experiment concluded that caretakers reporting short distance falls were much more likely to lie about the mechanism of injury than caretakers reporting falls from greater heights.³⁵

Furthering the subjectivity inherent in the diagnosis of shaken baby syndrome, the diagnosis of shaken baby syndrome takes place in the context of child abuse reporting laws. The incentives to report every *possible* instance of child abuse are compelling. Doctors would rather over report than under report child abuse because children cannot defend themselves from their abusers. Left unreported, child abuse can escalate, endangering a child's life. However, when the same bias for over-reporting child abuse finds its way into the development of or the testing of a scientific theory, the objectivity required for scientific reliability disappears.

IV. If shaken baby syndrome is a reliable scientific theory, then how does it explain clinical findings that directly contradict its necessary assumptions?

In deciding whether to admit expert testimony under Rule 702, the court should assess the extent to which the theory has been tested.³⁶ Although direct experimentation on infant brains cannot ethically be performed, the main assumptions upon which shaken baby syndrome rely have been shown to be false. Because the proponents of shaken baby syndrome couch their theory in absolute terms, one finding to contradict these absolute assumptions disproves the entire theory. When a theory is framed in the following terms, i.e., short distance falls do not cause the injuries encountered in shaken baby syndrome, it

³⁵ *Id.*

³⁶ *Rousseau*, 171 S.W.3d at 881.

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becomes false the moment it is disproved.

In order to determine whether the theory is false, one must first know the assumptions upon which the theory rests. Prosecutions for shaken baby syndrome must rely on certain assumptions in concluding that an infant who appears at the hospital in critical condition with a subdural hematoma and retinal hemorrhages must have been shaken violently by the last caregiver who was with the infant when the symptoms arose. Prosecutions for shaken baby syndrome arrive at this conclusion through a series of assumptions: (1) short distance falls cannot cause a subdural hematoma and retinal hemorrhages; (2) impact is not necessary to cause a subdural hematoma and retinal hemorrhages; (3) retinal hemorrhages are not present in accidental injuries; (4) a child cannot experience lucid intervals between the time of injury and the serious manifestations of the injury, such as inability to breath and loss of consciousness; (5) that subdural hematomas that develop from birth injuries always heal themselves; and (6) it is possible to shake an infant with sufficient force to cause a subdural hematoma and retinal hemorrhages without causing any injury to the child's neck, spinal cord, limbs, or chest.

This brief will refer to some of the most important and recent studies that show the falsity of the underpinnings of shaken baby syndrome. But this brief does not attempt to cite all of the relevant studies. Those studies are too numerous to discuss in this undertaking. Fortunately, several experts have already undertaken the task of compiling the evidence that proves the falsity of the main assumptions of the shaken baby syndrome in an amicus brief filed with a court of appeals in California. Defendant has attached the amicus brief to this

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motion as Exhibit 1 and incorporates by reference its contents.

(1) Short distance falls cannot cause a subdural hematoma and retinal hemorrhages.

Expert witnesses often testify that a fall from 2 to 10 feet cannot result in serious injury or death.³⁷ The evidence, however, proves otherwise. Falls from less than 4 feet can result in significant injury, and it has been documented that a fall from 42 inches has resulted in both subdural hemorrhaging and bilateral retinal hemorrhaging.³⁸ A study published in 2001 analyzed the Consumer Product Safety Commission's database on playground equipment falls. The study documents severe head injuries (including subdural hematomas and retinal hemorrhages) resulting from falls of less than 10 feet.³⁹ And according to a study in the Journal of Neurosurgery, shaking alone cannot cause these injuries but short distance falls can.⁴⁰

(2) Impact is not necessary to cause a subdural hematoma and retinal hemorrhages.

Perhaps the most telling sign that this assumption of the shaken baby syndrome is in doubt is the fact that experts began referring to the syndrome as shaken impact syndrome rather than shaken baby syndrome. The amicus brief attached as Exhibit 1 explains the studies that show the falsity of this common assumption underlying the shaken baby syndrome.

³⁷Werner Goldsmith, et al., *A Biomechanical Analysis of the Causes of Traumatic Brain Injury in Infants and Children*, 25 Am. J. of Forensic Medicine and Pathology 89, 95 (2004).

³⁸*Id.*

³⁹John Plunkett, *Fatal Pediatric Head Injuries Caused by Short Distance Falls*, 22 Am. J. of Forensic Medicine and Pathology 1 (2001).

⁴⁰*Anthropomorphic Simulations of Falls, Shakes and Inflicted Impacts in Infants*, 99 J. Neurosurgery (2003).

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(3) Retinal hemorrhages are not present in accidental injuries.

John Plunkett's study of playground injuries found that many of the children who suffered severe head injuries resulting from short falls also exhibited retinal hemorrhages.⁴¹ Furthermore, Norman Rosenberg, an ophthalmologist, created a fact pattern which included a child presenting with a subdural hematoma and retinal hemorrhages. Other ophthalmologists were asked to give a diagnosis of the case. Some concluded that the injuries resulted from abuse, others did not.⁴² And Andrea Tongue, also an ophthalmologist, concluded in her study that although it is possible that retinal hemorrhages result from shaken baby syndrome, there is no evidence that establishes that any type of retinal hemorrhage is pathenomonic for non-accidental trauma.⁴³ As the experts argue in the attached amicus brief, retinal hemorrhages can appear as a result of the brain swelling and the intercranial pressure that a subdural hematoma causes. Therefore, retinal hemorrhages are a symptom of head trauma, not a clear indicator of abuse.

(4) A child cannot experience lucid intervals between the time of injury and the serious manifestations of the injury.

A published study on lucid intervals took three cases of supposed "shaking" injuries and noted that the children experienced lucid intervals of 3 hours, 3 days, and 4 days after the "shaking." The study concludes that perpetrators cannot be narrowed down to the last person

⁴¹*Id.*

⁴²Norman Rosenberg, *Retinal Hemorrhage*, 10(5) Pediatric Emergency Care 303-05 (1994).

⁴³Andrea Tongue, *The Ophthalmologists Role in Diagnosing Child Abuse*, 98(7) Ophthalmology 1009-10 (1991).

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holding the baby.⁴⁴ For further falsification of the lucid interval assumption, see the attached amicus brief.

(6) It is possible to shake an infant with sufficient force to cause a subdural hematoma and retinal hemorrhages without causing any injury or bruising to the child's neck, spinal cord, limbs, or chest.

Proponents of the shaken baby syndrome have continually claimed that violently shaking an infant with enough force to cause the cascade of symptoms associated with shaken baby syndrome will not necessarily leave other signs of abuse. In fact, this absence of any sign of abuse is part of at least some experts' diagnosis of shaken baby syndrome. However, many experts are now questioning that assumption, arguing that violent shaking of the magnitude necessary to create the injuries associated with shaken baby syndrome would leave some other indicators of non-accidental trauma.⁴⁵

Mechanical engineer, Werner Goldsmith, teaches at the University of California, Berkeley. He contends that prosecutors are often overzealous, filing charges against innocent caregivers merely because the child had symptoms of shaken baby syndrome: bleeding in the subdura and the eyes, plus brain swelling. "The brain injuries that lead many prosecutors to file charges of child abuse can also be caused by falls or even result from chronic bleeding in the brain."⁴⁶ Goldsmith suggests that doctors need to look for other signs of abuse, such as injuries to the neck. He argues that "in order to do serious or fatal damage to an infant by

⁴⁴M. Nahelsky, J. Dix, *The Time Interval Between Lethal Infant Shaking and Onset of Symptoms: A Review of the Shaken Baby Syndrome Literature*, 16(2) Am. J. of Forensic Medicine and Pathology 154-57 (1995).

⁴⁵Goldsmith, *supra* note 41.

⁴⁶http://www.berkeley.edu/new/media/releases/2001/11/27_baby.html.

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shaking you have to have soft tissue neck damage. Yet, in 95 percent of cases, medical examiners do not look at the neck in autopsy. They look at the stomach, the abdomen, the head, but the neck is neglected.”⁴⁷

Certainly, shaking of a magnitude likely to cause shaken baby syndrome would break the infant’s neck or at least cause severe whiplash injuries. And shaking of that magnitude would likely be accompanied by bruising to the chest or limbs of the infants and probably breaking the ribs. The proponents have no explanation for the absence of signs of abuse in shaken baby cases other than circular logic – the infant appeared with a subdural hematoma and retinal hemorrhages and no indications of head impact, therefore shaking must have occurred, therefore shaking an infant does not necessarily produce independent signs of abuse.

V. If shaken baby syndrome is a reliable scientific theory, then what non-judicial function does it serve?

Shaken baby syndrome is not a diagnostic theory used for the purposes of treatment; it is an explanation of non-accidental head injury to an infant used primarily in the prosecution of child abuse cases. Most of the literature supporting the theory comes from child abuse specialists. Children are *treated* for closed head trauma or other known, defined injuries. Parents or other caregivers are *prosecuted* for shaken baby syndrome. Hence, shaken baby syndrome has been developed and used solely in reference to the judicial system, unlike DNA, which developed in the scientific realm for non-judicial purposes only to be used later as a tool in forensic science.

⁴⁷*Id.*

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VI. If shaken baby syndrome is a reliable scientific theory, then what is its potential error rate?

Proponents of the shaken baby syndrome provide no error rate for their theory. Some proponents admit that the theory's assumptions have been proven false, i.e., some children have died from short distance falls, some chronic subdural hematomas rebleed without intentionally inflicted trauma, and that retinal hemorrhages can occur with accidental head injuries. However, the proponents argue that the possibility of finding the constellation of injuries associated with shaken baby syndrome resulting from accidental injury or disease is remote. There are no studies to support just how remote this possibility is. Perhaps a remote possibility is 2%. Or maybe it is 25%. But when an expert is allowed to testify to a jury that the possibility that the child developed the injuries accidentally is remote to the extent of not even being a valid explanation, the expert is able to give unfair weight to the theory. Only when the theory has developed a potential error rate can a jury appropriately weigh the testimony of the expert. Without an error rate, the expert's testimony closely mirrors the *ipse dixit* testimony the Supreme Court forbid in *General Electric Co. v. Joiner*.⁴⁸

VII. If shaken baby syndrome is a reliable scientific theory, then why do so many experts in the field define shaken baby syndrome as a controversial theory?

Most of the experts publishing in the field of shaken baby syndrome recognize the lack of agreement regarding shaken baby syndrome's underpinnings. "Controversy surrounds the precise causation of the brain injury, the retinal and subdural hemorrhages, as well as the degree of force required and whether impact in addition to whiplash forces is needed."⁴⁹

⁴⁸522 U.S. 136, 146 (1997).

⁴⁹Harding, *supra* note 22.

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At least one expert is so skeptical of shaken baby syndrome, he likens proponents of shaken baby syndrome to “Flat Earthers.”⁵⁰ Dr. Joseph Davis, the retired director of the Miami-Dade County Medical Examiners Office and a leading forensic science expert, says that the use of shaken baby syndrome as a tool of prosecution conjures up “shades of Salem witchcraft trials.”⁵¹

John Plunkett, a forensic pathologist, has begun an intelligent debate about shaken baby syndrome, a debate that has played out in the medical journals. After calling into question many of the assumptions of shaken baby syndrome, Plunkett suggests:

we should abandon the term “shaken-infant syndrome” or “shaken-slammed infant syndrome and instead use an actual description of the injury mechanism (i.e., “rotational deceleration”) and admit that we do not know the force required to cause the injury. . . . We should cautiously interpret a caretaker’s story that is inconsistent with the physical findings, because the caretaker may not know the true history, especially if a lucid interval has occurred. . . . We need to differentiate between what we know to be true and what we think or hope to be true. The concept of shaken infant syndrome deserves to be examined and re-examined, even when we think we finally have it right.”⁵²

In response to Plunkett’s article, Brian Clark, an ophthalmologist, wrote:

In this field [professionals dealing with the shaken baby syndrome hypothesis] more than others, we are more readily prone to alter the facts to fit the hypothesis rather than alter the hypothesis to fit the facts. For example, if the accused admits to severely harming the child, we tend to believe because this fits our hypothesis, but if the accused offers an alternative apparently innocuous explanation we discount the explanation because it doesn’t fit the hypothesis. Published cases purporting to demonstrate less traumatic causes are attacked for their anecdotal data and for overlooking the real, more sinister explanation. This “illogical inconsistency”

⁵⁰ Kit R. Roane, *The CSI Effect*, U.S. News & World Report, Apr. 25, 2005, at 48.

⁵¹ *Id.*

⁵² John Plunkett, *Shaken Baby Syndrome and the Death of Matthew Eappen: A Forensic Pathologist’s Response*, 20(1) Am. J. of Forensic Medicine and Pathology 17-21 (1999).

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overlooks scientific process and forgets that the requirement for severe shaking forces is no more than a *avored* but *unproven* hypothesis.⁵³

If one thing can be said about shaken baby syndrome, it is that the theory is, at the very least, controversial.

VIII. Can the State meet its burden of establishing by clear and convincing evidence that the shaken baby syndrome is reliable if it merely demonstrates that the theory is accepted by many pediatricians and other medical practitioners?

Although many medical practitioners subscribe to the theory of shaken baby syndrome, that fact alone does not render expert testimony based on the theory admissible. As neurosurgeon Jan Leestma noted,

The crux of [shaken baby syndrome] is that a large number of physicians (pediatricians mostly) subscribe to the theory that when a baby is shaken . . . there is a pattern of pathology and clinical symptomology characteristic for this particular action and that . . . these features . . . virtually assure that shaking has occurred and that the individual present at the time is guilty of child abuse. . . . The problem with all of this is that the scientific evidence for many aspects of the “syndrome” have not been proven and in fact have largely been falsified by contrary data yet belief seems to hold sway over the methods and procedures of science.⁵⁴

If the Court were bound by the *Frye* standard, the State may have a better argument that under current law. However, *Daubert* and *Kelly* require a much more exacting standard – the Court must make an independent assessment of reliability. And the State carries the burden of demonstrating the *reliability* of its theory through clear and convincing evidence. To say that the State may skip that requirement because it can demonstrate general acceptance is to collapse *Daubert* into the old *Frye* analysis, a result the Supreme Court and the Texas

⁵³Clark, *supra* note 36 (emphasis in original) (internal citations omitted).

⁵⁴Jan Leestma, *Shaken Baby Syndrome: Putting Evidence Based Medicine to the Test?*, <http://www.scienceboard.net/community/perspectives.24.html>.

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Court of Criminal Appeals could not have intended. The acceptance of the shaken baby syndrome theory by many medical practitioners simply does not demonstrate reliability. As John Plunkett noted, "The plural of anecdote is not data, and the sum of 'vast clinical experience' is not science."⁵⁵ To present expert evidence of shaken baby syndrome to the jury, the State must demonstrate by clear and convincing evidence that shaken baby syndrome can stand on its own when subjected to rigorous scientific testing. The State cannot carry that burden in this case.⁵⁶

Conclusion

State prosecutors and witnesses who are involved in shaken baby syndrome or shaken baby impact syndrome cases have claimed that only a small percentage of doctors do not agree with the state's shaken baby theory. However, the opposite is likely true. There is no doubt

⁵⁵Plunkett, *supra* note 56.

⁵⁶The following additional material is appended to this motion in support of the relief requested:

1. Shaken Baby Syndrome: A Biomechanics Analysis of Injury Mechanisms, Bandak, Forensic Science International, Feb. 2005.
2. "Shaken Baby Syndrome: A Questionable Scientific Syndrome and a Dangerous Legal Concept," Genie Lyons, 2003 Utah Law Review 1109.
3. Shaken Baby /Impact Syndrome: Flawed Concepts and Misdiagnoses (Based on a Review of Twenty-Two Cases), Buttram, Sept. 3, 2002.
4. Shaken Baby Syndrome Diagnosis on Shaky Ground, Scheibner, Journal of the Australian College of Nutrition & Environmental Medicine, Vol. 20, No. 2, August 2001.
5. Shaken Baby Syndrome: The Vaccination Link, Scheibner, Nexus, Vol. 5, No. 5, August - September 1998.
6. Shaken Baby Syndrome: Fundamental Questions, Uscinski, British Journal of Neurosurgery, April 2002.
7. The Shaken Baby Syndrome, Uscinski, Journal of American Physicians and Surgeons, Vol. 9, No. 3, Fall 2004.
8. The Evidence Base for Shaken Baby Syndrome, British Medical Journal, March 2004.
9. Unexplained Subdural Hematoma in Young Children: Is It Always Child Abuse, Fung, Pediatrics International (2002).
10. Significance of a Subdural Hematoma in a Child with External Hydrocephalus, Pittman, Pediatric Neurosurgery, 2003.
11. Retinal Hemorrhages: Evidence of Abuse or Abuse of Evidence?, The American Journal of Forensic Medicine and Pathology, Volume 22(4), December 2001.

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that the vast majority of doctors have no opinion on shaken baby syndrome, have never studied it or been involved in it in any way. When the universe of doctors who have studied the issue is considered, it is likely that a number much greater than a small minority find the shaken baby syndrome theory to be without a scientific basis.

Moreover, even if there is a large part of the medical establishment that supports the shaken baby syndrome theory, it is clear that there is an ever increasing number of doctors who have joined the ranks of those who do not support this theory. Among the doctors who refute the state's shaken baby theory are the medical examiners of two of the largest counties in Texas: Bexar and Tarrant Counties. The former medical examiner of Dallas County has also stated his belief that the shaken baby theory is incorrect. Additionally, doctors from a variety of disciplines from around the world have gone on record as stating that the theory is not scientifically sound.

The fact that the state can produce witnesses with medical degrees who support the theory is not sufficient to render it admissible in court. If this was the test, then any theory supported by a person with a degree would be admitted. Clearly, that is not the standard.

Moreover, even if the state claims that there are many doctors who believe in the theory, that alone does not make it admissible. The history of medicine is replete with examples of theories that were widely accepted that were later shown to be bogus.

Child abuse is a serious and tragic crime. When doctors observe indications that a child has been abused by a caregiver they are right to investigate further. But in the well-intended attempts to prosecute those who abuse children, we should not dispense with our evidentiary

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and constitutional standards. We should continue to insist that when scientific theory is used to convict a person, a person assumed innocent of the charges, the science is reliable. Many criminal defendants have been wrongfully convicted because experts testified to forensic science later proven false by DNA exonerations. Other experts have sealed defendants' fates with testimony that overstated the scientific findings.

Just as eyewitness testimony conducted without the proper protocols will almost certainly mislead jurors, experts whose opinions are based on unreliable scientific theories will lead juries to convict innocent people.⁵⁷ When unreliable scientific testimony reaches the jury, its prejudicial effects cannot be overcome through cross-examination. And where shaken baby syndrome is the issue, defendants will never have the opportunity to collaterally challenge the conviction with definitive scientific evidence like DNA. If ever there were an instance in which demanding standards of reliability should be applied, it is in this case.


The shaken baby syndrome theory is ripe for a thorough and searching review and a serious application of the trial court's gatekeeping function.

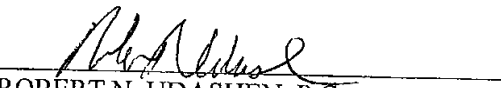
Based on the foregoing, Defendant prays that the court set this motion for a hearing in order to determine whether the state's proposed scientific evidence of shaken baby syndrome is admissible under Rule 702, T. R. Evid. and, after the hearing, to find this evidence to be inadmissible.

⁵⁷A related question is whether when the scientific basis of the state's theory of prosecution is thoroughly rejected by numerous highly qualified experts, can there ever be a finding of guilt beyond a reasonable doubt?

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Respectfully submitted,


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CERTIFICATE OF SERVICE

On this 17 day of February, 2006, a true and correct copy of the foregoing Defendant's Motion to Exclude Expert Testimony Pursuant to Texas Rule of Evidence 702 was delivered to Patricia Hogue, Assistant District Attorney, Frank Crowley Courts Bldg., 133 N. Industrial Blvd., Dallas, Texas 75207.


GARY A. UDASHEN

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ORDER

On this the _____ day of _____, 2006, came on to be heard the foregoing Defendant's Motion to Exclude Expert Testimony Pursuant to Texas Rule of Evidence 702, and same is hereby GRANTED.

JUDGE

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"Shaken Baby Syndrome: A Questionable Scientific Syndrome and a Dangerous Legal Concept," Genie Lyons, 2003 Utah Law Review 1109.	2
Dural haemorrhage in non-traumatic infant deaths: does it explain the bleeding in 'shaken baby syndrome'?, Geddes, Tasker, Hackshaw, Nickols, Adams, Whitwell and Scheimberg, Neuropathology and Applied Neurobiology (2003)	3
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A Biomechanical Analysis of the Causes of Traumatic Brain Injury in Infants and Children, Goldsmith and Plunkett, The American Journal of Forensic Medicine and Pathology, Vol. 25(2), June 2004	5
Study Reveals Household Falls May Produce More Severe Brain Injuries in Infants than Previously Thought, June 28, 2003	6
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Shaken Baby Syndrome Diagnosis on Shaky Ground, Scheibner, Journal of the Australian College of Nutrition & Environmental Medicine, Vol. 20, No. 2, August 2001.	11
Shaken Baby Syndrome: The Vaccination Link, Scheibner, Nexus, Vol. 5, No. 5, August - September 1998.	12
Shaken Baby Syndrome: Fundamental Questions, Uscinski, British Journal of Neorsurgery, April 2002.	13
The Shaken Baby Syndrome, Uscinski, Journal of American Physicians and Surgeons, Vol. 9, No. 3, Fall 2004.	14
The Evidence Base for Shaken Baby Syndrome, British Medical Journal, March 2004.	15
Unexplained Subdural Hematoma in Young Children: Is It Always Child Abuse, Fung, Pediatrics International (2002).	16
Significance of a Subdural Hematoma in a Child with External Hydrocephalus, Pittman, Pediatric Neurosurgery, 2003.	17
Retinal Hemorrhages: Evidence of Abuse or Abuse of Evidence?, The American Journal of Forensic Medicine and Pathology, Volume 22(4), December 2001	18

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STATE OF CALIFORNIA, COURT OF APPEAL

FOURTH APPELLATE DISTRICT, DIV. I

THE PEOPLE OF THE
STATE OF CALIFORNIA,

Plaintiff-respondent,

v.

MANJIT K. BASUTA,

Defendant-appellant

) D034429
)
) SCD 130926
)
) APPLICATION AND
) MOTION TO FILE
) BRIEF OF THE AMICI,
) PHYSICIANS AND
) BIO-SCIENTISTS
)

**MOTION FOR LEAVE TO PRESENT STATEMENT OF
AMICI CURIAE IN SUPPORT OF APPELLANT BASUTA'S
APPEAL AND STATEMENT OF AMICI CURIAE
IN SUPPORT OF RELIEF**

Pursuant to Rule of Court 14(c), applicants, (hereinafter "*Amici Curiae*"), by and through their attorney, Lisa A. Rasmussen, to respectfully submit this motion for leave to present their statement of *Amici Curiae* in support of the appellant, Mrs. Manjit Basuta (hereinafter "Ms. Basuta"), and this statement of *Amici Curiae* in

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support of her request for relief. As grounds therefore, the *Amici Curiae* respectfully submit as follows:

Amici Curiae are physicians and bio-scientists who are familiar with the medical condition and diagnosis called the Shaken Baby Syndrome. We are informed that in the appellant's case, prosecution medical opinion testimony was given to the effect that: 1) that shaking alone in an otherwise healthy child can cause a subdural hematoma; 2) that non-traumatic new bleeding in an existing subdural hematoma will always cause only relatively minor symptoms; 3) that a child suffering from an ultimately fatal brain injury will not experience any lucid interval; 4) that short-distance falls by children are never fatal; and, 5) that retinal hemorrhage occurs only in shaken babies.

This is relevant to the testimony of the state's medical experts and also directly related to the issue posed in the Appellant's opening brief, argument number IV: that the Kelly rule should apply to expert testimony on shaken baby syndrome as a causation doctrine. We know through our own experience and through the data published in peer-

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reviewed scientific journals that each of the five beliefs stated above are false. We wish to present to the Court the published data so stating. It is our opinion that if the medical opinions proffered by the state in appellant's case were put to the test of rigorous scrutiny by the scientific community, and therefore acceptance, those opinions would fail to meet that standard. We understand that appellant has challenged these opinions in her brief and the material we provide in our brief fully supports that challenge.

The attached brief of the *Amici Curiae* raises several issues that may not be addressed by either party in their submissions to this Court. These issues are relevant to the disposition of this case. For efficiency sake we have attached our proposed brief. If the application, we hereby request that the application be deemed the brief of the *Amici*.

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For these reasons, *Amici Curiae* respectfully submit this motion and attached statement to the Court in support of Ms. Basuta's request for relief.

Dated:

Respectfully Submitted,

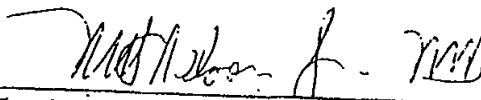
July 7, 2000



Ronald K. Wright, M.D., J.D.
[Original Signature on File]

Dr. Wright, a forensic pathologist in private practice, is the former Medical Examiner of Broward County, Florida. He is board certified by the American Board of Pathology in Anatomical and Clinical Pathology and Forensic Pathology. He is a diplomat of the National Board of Medical Examiners and he is licensed to practice medicine in Missouri, Vermont and Florida. He is also a member of the Florida State Bar. [See Exhibit M.]

July 10, 2000

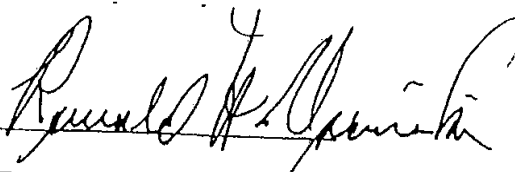


Marvin D. Nelson, Jr., M.D., F.A.C.R.
[Original Signature on File]

Dr. Nelson is a pediatric neuroradiologist. He is the Chairman of the Department of Radiology at Children's Hospital in Los Angeles and an Associate Professor of Radiology at the University of Southern California School of Medicine. [See Exhibit G.]

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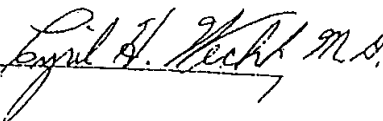
July 10, 2000



Ronald H. Uscinski, M.D.
[Original Signature on File]

Dr. Uscinski is neurologist. He is certified by the American Board of Neurological Surgery. He is currently the Clinical Assistant Professor of Surgery, Division of Neurological Surgery at Georgetown University Medical Center in Washington, D.C., and he is the Clinical Assistant Professor of Pediatric Neurosurgery in the Pediatric Department at Georgetown University Hospital, also in Washington, D.C. [See Exhibit J.]

July 12, 2000

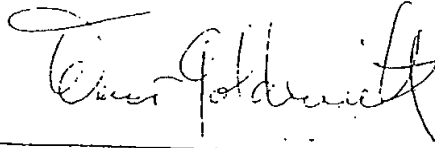


Cyril H. Wecht, M.D., J.D.
[Original Signature on File]

Dr. Wecht is the Director of Forensic Pathology at St. Francis Central Hospital in Pittsburgh, Pennsylvania and the Coroner of Allegheny County, Pennsylvania. He is licensed to practice medicine in Pennsylvania, California and Maryland and he is a diplomat of the National Board of Medical Examiners. He is certified by the American Board of Pathology in Anatomical and Clinical Pathology and Forensic Pathology. He is also a charter diplomat of the American Board of Legal Medicine. [See Exhibit K.]

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July 12, 2000



Werner Goldsmith, Ph.D.
[Original Signature on File]

Dr. Goldsmith is a Professor of the Graduate School of Mechanical Engineering at the University of California, Berkeley. He is a member of the National Academy of Engineering and an honorary member of the American Society of Mechanical Engineers. He is also a registered mechanical and safety engineer in the State of California. Dr. Goldsmith has testified for both the prosecution and the defense as an expert witness in the area of biomechanics. [See Exhibit D.]

NOTE: Dr. Goldsmith also prepared a supplemental document in support of the *Amici Curiae Brief* which addresses issues not addressed in this brief. This supplemental document is attached to the *Amicus Brief* as Exhibit A.

July 13, 2000

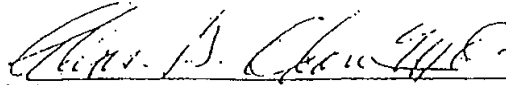


Thomas A. Carlstrom, M.D.
[Original Signature on File]

Dr. Carlstrom is a neurologist in Des Moines, Iowa. He has been a member of the American Board of Neurological Surgery since 1981 and he is also a member of the American Association of Neurological Surgeons. [See Exhibit C.]

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July 13, 2000



Charles B. Odom, Jr., M.D.
[Signature on File]

Dr. Odom is forensic pathologist and the former Medical Examiner for the Dallas County Medical Examiner's Office in Dallas, Texas. He retired on July 1, 1999. He is licensed to practice medicine in Louisiana, Texas and New York. He is board certified by the American Board of Pathology in Anatomic and Forensic Pathology and by the American Board of Obstetrics and Gynecology. [See Exhibit H.]

July 18, 2000



Jan Edward Leestma, M.D., M.M.
[Original Signature on File]

Dr. Leestma is a forensic neuropathologist at the Chicago Institute for Neurosurgery and Neuroresearch. He is board certified by the American Board of Pathology in Anatomic Pathology and Neuropathology. [See Exhibit F.]

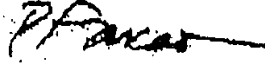
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July 19, 2000



Phillip Incao, M.D.
[Signature on File]

Dr. Incao is a general private practitioner in Denver, Colorado. He is certified to practice medicine in New York and in Colorado. He has testified as an expert witness in New York, Vermont, Colorado and Michigan. [See Exhibit E.]

July 19, 2000



Harold E. Buttram, M.D., F.A.A.E.M.
[Original Signature on File]

Dr. Buttram is a family physician in private practice in Quakertown, Pennsylvania. He is a diplomat of the International Board of Environmental Medicine and is licensed to practice medicine in the state of Pennsylvania. [See Exhibit B.]

July 24, 2000

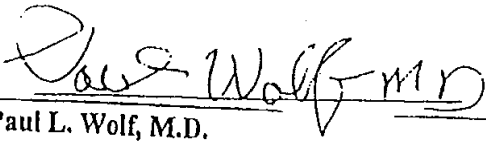


Peter J. Stephens, M.D.
[Original Signature on File]

Dr. Stephens is a forensic pathologist in Cedar Rapids, Iowa. He is board certified by the American Board of Pathology in Anatomical and Clinical Pathology as well as Forensic Pathology. [See Exhibit I.]

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August 1, 2000


Paul L. Wolf, M.D.
[Original Signature on File]

Dr. Wolf is a Clinical Professor of Pathology at the University of California San Diego. He is the Director of Autopsy Service, Director of the Hematology Lab and Assistant Director of the Chemistry Lab at the VA Hospital in San Diego. [See Exhibit L.]

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STATE OF CALIFORNIA, COURT OF APPEAL
FOURTH APPELLATE DISTRICT, DIV. 1

THE PEOPLE OF THE)	D034429
STATE OF CALIFORNIA,)	
)	SCD 130926
Plaintiff-respondent,)	
)	
MANJIT K. BASUTA,)	AMICUS BRIEF
)	
Defendant-appellant)	
_____)	

I.
INTRODUCTION

We are bioengineers and physicians, scientists who have studied the biomechanics and morphologic expressions of infant head injury, and have testified in criminal matters. Many of us treat adults and children with head injuries. Despite California's People v. Kelly¹ rule, the law does not require any showing of reliability or general

¹ *People of the State of California v. Kelly* (1976) 17 Cal.3d 24.

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acceptance within the scientific community in order for a physician to render what are characterized as "medical opinions." This brief addresses our concern of the widespread tendency of child abuse "experts" who give testimony which is incompatible with empirical data. Specifically our concern is that such testimony, which either contradicts or is inadequately supported by empirical data, will be used to influence juries who are unable to distinguish between impressive testimony and valid science.

Under Kelly, in order to give expert scientific testimony, the proponent must show that the testimony and opinions are generally accepted in the relevant scientific field.² Medical opinion evidence is an exception to this rule in California. The Kelly rule, if applied to prosecution experts on shaken baby syndrome (SBS), would bar their opinion testimony if such testimony states that subdural hemorrhage and retinal hemorrhage in an infant or young child is diagnostic for the so-called "shaken baby syndrome" or "shaken-slammed baby

² *People of the State of California v. Leahy* (1994) 8 Cal.4th 587.

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syndrome." Such opinions are based upon five specific articles of faith, which are either demonstrably wrong or scientifically unproven. Further, these beliefs and statements violate rules of physics developed during the past 350 years and fundamental concepts of biomechanical engineering used for the past 60 years. Misplaced belief in the validity of this syndrome can lead to the conviction of innocent persons. These beliefs, stated in sworn testimony by state medical testimony, are: 1) That shaking alone in an otherwise healthy child may cause a subdural hematoma leading to death; 2) That non-intentional "new" bleeding in an existing subdural hematoma will always cause only relatively minor bleeding, and that a symptomatic or ultimately fatal new bleeding requires significant proximate non-accidental trauma; 3) That a child suffering from an ultimately fatal brain injury will not experience any lucid interval; 4) That short-distance falls by children are never fatal; and 5) That retinal hemorrhage occurs only in shaken babies.

These five opinions are unproven, anecdotal conjectures

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masquerading as science. If accepted as fact, testimony regarding these opinions can cause incalculable damage. History has demonstrated that pseudo-scientific hysteria (for example the Salem witch trials in the 17th century, the child satanic ritual abuse scare, the McMartin child molestation hoax of the early 1990's and the more recent notion of repressed memory syndrome) can ruin innocent people's lives. Time has proven all of the above to be myths, made credible at the time by social hysteria and supported by expert medical "opinion." Absent any change in the law by this court or extreme sensitivity by trial judges, the promulgation of these myths is likely to lead to grave injustices in which innocent persons may be wrongly convicted based on jury reliance upon opinions unsupported, if not contradicted, by empirical data.

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II.

BELIEF NUMBER ONE:

"SHAKING ALONE IN AN OTHERWISE HEALTHY
CHILD MAY CAUSE A SUBDURAL HEMATOMA
LEADING TO DEATH"

This belief is the conclusory apogee of beliefs two, three, four and five. Guthkelch³ and Caffey⁴ described the "shaken-whiplash syndrome" in the early 1970's. This syndrome was elucidated in the context of a battered child with multiple, multidirectional-force injuries. It was postulated that the weak neck muscles and relatively large head size of an infant made him or her particularly susceptible to subdural injuries caused by shaking.⁵ "There was no experimental model to prove or disprove their theory, and no disinterested witness had ever observed a shaking, but the theory was gradually accepted as

³
Guthkelch AN. Infantile subdural hematoma and its relationship to whiplash injury. *BMJ* 1971; 11:430-1.

Caffey J. *On the theory and practice of shaking infants: its potential residual effects of permanent brain damage and mental retardation.* *AM J Dis Child* 1972; 124:161-9.

See Plunkett J. *Shaken Baby Syndrome and the Death of Matthew Eappen: A Forensic Pathologist's Response.* *American Journal of Forensic Medicine and Pathology* 1999; 20: 17-21.

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fact: subdural hemorrhage and retinal hemorrhage in an unconscious or dead child is diagnostic for a shaken infant." ⁶

Several years later, Duhaime et al. developed a model in an attempt to demonstrate what, if any, infant susceptibility there was to shaking. This team of scientists was unable to generate the force required to cause death or serious brain injury unless the head was impacted against a solid surface.^{7, 8} The authors of those studies concluded that "severe head injuries commonly diagnosed as shaking injuries require impact to occur and that shaking alone in an otherwise normal baby is unlikely to cause the shaken baby

⁶ *Ibid.*

⁷ Duhaime A-C, Gennarelli TA, Thibault LE, et al. The Shaken Baby Syndrome: a clinical, pathological, and bio-mechanical study. *J Neurosurgery* 1987; 66:409-15. In appellant's case, Dr. Michael Jones conducted a study replicating the Duhaime study with similar results - shaking alone did not generate sufficient force to cause death or serious brain injury.

⁸ Duhaime A-C, Alario AJ, Lewander WJ, et al. Head injury in very young children: mechanisms, injury types and ophthalmologic findings in 100 hospitalized patients younger than two years of age. *Pediatrics* 1992; 90:179-85.

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syndrome."⁹

Despite these findings, which were based on actual experiments and case studies, prosecution "experts" across the country continue to state and testify that fatal infant brain injury, which results in a subdural hematoma, is the result of a "shaking". This type of testimony is purely conjectural and has no scientific basis. More importantly, it cannot meet the standard of general acceptance and reliability in the medical and other scientific community because it is a belief unsupported and contradicted by empirical data.

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⁹ *Ibid.*

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III.

BELIEF NUMBER TWO:

"NON-TRAUMATIC NEW BLEEDING IN AN EXISTING SUBDURAL HEMATOMA WILL ALWAYS CAUSE ONLY RELATIVELY MINOR BLEEDING, AND A SYMPTOMATIC OR ULTIMATELY FATAL NEW BLEEDING REQUIRES SIGNIFICANT PROXIMATE NON-ACCIDENTAL INJURY"

The statement that rebleeding requires new trauma is incorrect.

The only successful experimental model for producing a chronic subdural hematoma required injecting cerebrospinal fluid mixed with blood into the subdural space.¹⁰ It has been demonstrated that the neomembrane surrounding an organizing subdural hematoma may itself bleed and that expansion of a subacute/chronic subdural hemorrhage may cause new bridging veins to rupture and that an acute clot may predispose to new bleeding.^{11, 12}

¹⁰
Watanabe S, Shimada HJ, Ishiis S. Production of clinical form of chronic subdural hematoma in experimental animals. *J Neurosurgery* 1972; 37: 552-61.

¹¹
Kawakami Y, Chikama M, Tamiya T, et al. Coagulation and fibrinolysis in chronic subdural hematoma. *Neurosurgery* 1998; 25:25-9.

¹²
Parent AD, Pediatric chronic subdural hematoma: a retrospective comparative

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There are documented cases in which children have bled extensively from an existing subdural hematoma in which no "new" trauma or only minor trauma was thought to be the cause. It is common for prosecution experts to testify that "minor" rebleeds from an existing subdural hematoma may occur, but that those rebleeds are insignificant and that a fatal or serious rebleed can only occur from vigorous shaking. The essence of this argument is that a prior existing injury cannot cause death, serious injury to the brain or significant bleeding.

Some prosecution experts have gone so far as to testify that a prior existing injury cannot spontaneously rebleed. Not only is there no data to support this conclusion, there are documented cases to the contrary. For example, in In re Christopher Randall Braddy¹³ (a Georgia case that went to trial in December 1999, resulting in an acquittal of the infant's father) involved an infant who was taken to

analysis. *Pediatric Neurosurgery* 1992; 18: 266-71.

¹³ Superior Court number 07699J0931, Houston County, Georgia.

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the hospital after he stopped breathing in his father's arms following a visit to the doctor earlier that day for projectile vomiting. The child was placed on a monitor and a CT scan indicated that he had a subdural hematoma and unilateral retinal hemorrhages. He remained hospitalized for six weeks and was constantly monitored. During that time, he had several spontaneous re-bleeds that were documented by sequential CT scans.

New bleeding in an established subdural hematoma may occur spontaneously¹⁴ and without new trauma. In the cited example, the child was in the hospital under the care of a physician, not under the care of a parent or caretaker.

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¹⁴

Lindenberg R. Mechanical injuries of the brain and meninges. *In: Medicological Investigation of Death*. Ed., Spitz W. Third Edition. Thomas (Springfield). 1993. P. 585-636.

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IV.

BELIEF NUMBER THREE:

"A CHILD SUFFERING FROM AN ULTIMATELY
FATAL INJURY WILL NOT EXPERIENCE ANY
LUCID INTERVAL"

At least some children with head injuries have a documented lucid interval prior to the development of symptoms, including those who subsequently die.^{15, 16, 17} A study currently in review for publication documents 12 children (out of 18) with lucid intervals followed by unconsciousness and death, in which the fatal brain injury was due to a short-distance fall (one of which was videotaped).¹⁸

¹⁵

Nashelsky MB, Dix JD. The time interval between lethal infant shaking and onset of symptoms: a review of the shaken baby syndrome literature. *Am J Forensic Med Pathol* 1995; 16:154-7.

¹⁶

Plunkett J. Restricting the time of injury in fatal inflicted head injuries [leuer]. *Child Abuse Negl* 1998; 22:943-4.

¹⁷

In re: the interest of John Doe, 97-JA-136. DuPage County, Illinois, 1997.

¹⁸

Plunkett J. Fatal Pediatric Head Injury Caused by Short-Distance Falls (In Review).

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All of the experimental data regarding lucid intervals and cerebral trauma are on mature adult human, primate and other animal brains. Adult data, which uses diffuse axonal injury to explain prolonged unconsciousness in head-injury victims, have been applied to child injuries with no scientific basis or experimentation on children or infant primates to justify the extrapolation.^{19, 20} Despite a lack of evidence that this data can be scientifically applied to children, experts continue to testify that shaken infants never have a lucid interval.²¹

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¹⁹

Plunkett J. Shaken baby Syndrome and the Death of Matthew Eappen, *supra*, fn 5.

²⁰

Plunkett J. Restricting the Time of Injury in Fatal Inflicted Head Injuries, *supra*, fn. 16.

²¹

Willman KY, Bank DE, Senac M, et al. Restricting the time of injury in fatal inflicted head injuries. *Child Abuse Negl.* 1997; 21:929-40.

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V.

BELIEF NUMBER FOUR:

"SHORT-DISTANCE FALLS BY CHILDREN
ARE NEVER FATAL"

Isolated reports of observed fatal falls and biomechanical analysis using experimental animals and adult human volunteers indicates the potential for serious head injury or death from as little as a two-foot fall.^{22, 23, 24, 25, 26} An injury resulting in a subdural

²²

Gurdjian ES, Lissner HR, Patrick LM. Protection of the head and neck in sports. *J Am Med Assoc* 1962; 182-509.

²³

Gurdjian ES, Roberts UL, Thomas LM. Tolerance curves of acceleration and intracranial pressure and protective index in experimental head injury. *J Trauma* 1966; 6:600-604.

²⁴

Mahajan BM, Beine WB. Impact attenuation performance of surfaces installed under playground equipment: report to the Consumer Product Safety Commission. US Department of Commerce, National Bureau of Standards, Washington, DC: Feb. 1979. Publication No. NBSIR 79-1707.

²⁵

Reichelderfer TE, Overbach A, Greensher J. X-rated playgrounds? *Pediatrics* 1979; 64-962-63.

²⁶

Collantes M. Playground surfaces and head injury. Evaluation of the importance of using the Head Injury Criterion (HIC) to estimate the likelihood of head impact injury as a result of a fall onto playground surface materials. US Consumer Product Safety Commission (1990). Washington, DC 20207. Available from:

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hematoma in an infant may be caused by an accidental fall.^{27, 28, 29} A recent report documented the findings in 7 children seen in a pediatric hospital emergency room after an accidental fall of 2-5 feet who had subdural hemorrhage, no loss of consciousness and no symptoms.³⁰ Further, the study previously cited and currently under review for publication documents 18 cases of fatal brain injury caused by falls from as little as 22 inches from playground equipment onto a non-yielding surface.³¹

This empirical data specifically contradicts the testimony of

URL: <http://www.cpsc.gov/cpscpub/pubs/3005.html>.

²⁷
Aoki N, Masuzawa H. Infantile acute subdural hematoma. *J Neurosurgery* 1984; 61:272-280.

²⁸
Greenes DS, Schutzman SA. Occult intracranial injury in infants. *Ann Emerg Med* 1998; 32:680-686.

²⁹
Howard MA, Bell BA, Uttley D. The pathophysiology of infant subdural hematomas. *Br. J Neurosurgery* 1993; 7:355-365.

³⁰
Greenes DS, Schutzman SA. Occult intracranial injury in infants. *Ann Emerg Med* 1998; 32:680-686.

³¹ See Plunkett, J, *supra*, fn. 18.

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prosecution experts who claim that short-distance falls are never fatal.

VI.

BELIEF NUMBER FIVE

**"RETINAL HEMORRHAGE OCCURS
ONLY IN SHAKEN BABIES"**

Perhaps the most dangerous and abused belief is the statement that retinal hemorrhage in an infant can only be caused by "shaking". Almost all prosecution experts (including Dr. Davis in this trial) testify that retinal hemorrhage is the "hallmark" of shaken baby syndrome. Retinal hemorrhage may be caused by ligating the central retinal vein or its tributaries, suddenly increasing intracranial venous pressure.^{32, 33} Retinoschisis, the detachment of the retina from the supporting structures, is the result of breakthrough bleeding and

³²

Smith DC, Kearns TP, Sayre GP. Pre-retinal and optic nerve sheath hemorrhage: pathologic and experimental aspects in subarachnoid hemorrhage. *Trans Am Acad Ophthalmol Otolaryngol* 1957; 61:201-211.

³³

Lehman RAW, Krupin T, Podos SM. Experimental effect of intracranial hypertention upon intraocular pressure. *J Neurosurgery* 1972; 36: 60-66.

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venous stasis, not violent shaking.^{34, 35} In reality, any sudden increase in intracranial pressure may cause retinal hemorrhage.^{36, 37, 38, 39} Furthermore, retinal and optic nerve sheath hemorrhages associated with a ruptured vascular malformation are due to an increase in venous pressure, not extension of blood along extravascular spaces.^{40.}

³⁴

Greenwald MJ, Weiss A, Osterle CS, Friendly DS (with "Discussion" by Tongue AC). Traumatic retinoschisis in battered babies. *Ophthalmol* 1986; 93: 618-624.

³⁵

Vanderlinden RG, Chishold LD. Vitreous hemorrhages and sudden increased intracranial pressure. *J Neurosurgery* 1974; 41: 167-176.

³⁶

Kirshner RH, Stein RJ. The mistaken diagnosis of child abuse. A form of medical abuse? *Am J Dis Child* 1985; 139: 873-875.

³⁷

Weedn VW, Mansour AM, Nichols MM. Retinal hemorrhage in an infant after cardiopulmonary resuscitation. *Am J Forens Med Path* 1990; 11: 79-82.

³⁸

David DB, Mears T, Quinlan MP. Ocular complications associated with bungee jumping. *Br. J. Ophthalmol* 1994; 78:234-235.

³⁹

Jain BK, Talbot EM. Bungee jumping and intraocular hemorrhage. *Br J Ophthalmol* 1994; 78: 236-237.

Smith DC, Kearns TP, Sayre GP. Pre-retinal and optic nerve sheath hemorrhage: pathologic and experimental aspects in subarachnoid hemorrhage. *Trans Am Acad Ophthalmol Otorlaryngol* 1957; 61:201-211.

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41, 42, 43 Simply stated, retinal hemorrhage may occur whenever intracranial pressure exceeds venous pressure or whenever there is venous obstruction. Retinal hemorrhages are not diagnostic of a shaken infant.

CONCLUSION

The beliefs that shaking alone in an otherwise healthy child will cause a subdural hematoma; that a re-bleed from an existing subdural hematoma will always cause only relatively minor symptoms; that a child suffering from an ultimately fatal brain injury will not experience any lucid interval; that short-distance falls by children are never fatal; and that retinal hemorrhage occurs only in shaken babies are not supported by empirical data. These beliefs

41

Lehman RAW, Krupin T, Podos SM. Experimental effect of intracranial hypertension upon intraocular pressure. *Supra*, fn. 30.

42

Vanderlinden RG, Chisholm LD. Vitreous hemorrhages and sudden increased intracranial pressure. *J Neurosurg* 1974; 41: 167-176.

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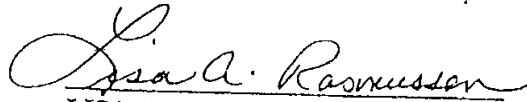
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cannot and should not be used as a basis of proof that a child has
suffered non-accidental injury.

Respectfully submitted,

August 2, 2000



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COLLEGE OF ENGINEERING
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This document is prepared in support of the Amici Curiae Brief filed on behalf of appellant Manjit K. Basuta vs. the People of the State of California. The undersigned fully endorses the five Beliefs stated in the motion for an appeal by the defendant-appellant, but would also like to forcefully address several additional issues concerning this case.

1) This writer wants to add a crucial point to the amicus brief that is not mentioned in the five points raised. This issue concerns the fact that if a baby or infant is shaken to the point of potential serious brain damage, there must be evidence of concomitant neck trauma. The weight of the head of an infant, depending on age, is a substantial fraction of its total weight, of the order of 20 percent for a 12-13 month old child. Conversely, the neck is an extremely fragile connector of the head to the body, and unless the body and head are shaken in complete unison, a practical impossibility, there will be major trauma to the cervical region. The writer has examined all of the reports of the National Library of Medicine (Medline) dealing with the so-called shaken-baby syndrome. In all these tracts, only one discourse addresses the question of concomitant neck trauma, and in that case, five of six fatalities exhibited serious hematomas and contusions of the cervical spinal cord. Since no cervical damage was reported in the case of Oliver Amaral/Smith, it is extremely unlikely that his fatal injury resulted from the repetitive shaking associated with the "shaken-baby syndrome".

2) It is reported that there was evidence of an impact in the forehead region of the head of the child. There is currently a misconception resulting in a misnomer in the medical profession that labels such trauma as the "shaken

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baby/impact syndrome." As someone who is internationally known as the "father of impact" by virtue of the publication of the first technical monograph in the field more than 40 years ago, that systematized the subject, I can state categorically that shaking and impact are two completely different mechanisms and that their application to an infant or child will have totally different consequences, both physically and in terms of trauma. To confuse the issue by linking two completely different actions in the same phrase promotes misunderstanding of what actually took place. As a result, this may not only impair proper remedy for apparent trauma, but could also easily criminally implicate caregivers that are, in fact, not at fault.

3) It has been demonstrated in the only scientific investigation to date of the "shaken-baby syndrome" (Duhaime, et al, J. Neurosurgery, v. 66, 409-15, 1987) that the acceleration levels produced by shaking are 50-100 times lower than those produced by impact. The level of acceleration in a shaking action that is not prolonged or frequently repeated is such that lethality should not occur unless there was prior disposition for trauma, such as a previously damaged vessel that did not heal properly, i.e. a rebleed. Conversely, an impact produces levels of acceleration and force that are at best dangerous and frequently lethal. These levels have been researched by numerous authorities and their reports have resulted in tolerance levels used by the government and industry in the design of vehicles and protective devices for the head. The cited bruise on the right side of his forehead had to be produced by an impact, such as a fall. This is by far the most plausible explanation for his deteriorating physical condition and ultimate death due to intercranial bleeding or rebleeding aggravated by a prior subdural hematoma.

4) It is the understanding of the undersigned that a biomechanical engineer was not permitted to testify in part because the trial judge viewed the issue as one "of first impression" and because there was no application of

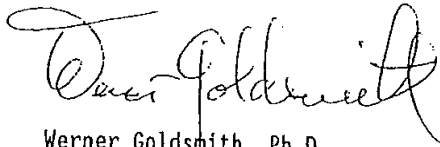
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biomechanical principles to actual head injuries in children. I must most strongly disagree with these positions. During the past 20 years, I have testified in numerous instances both for the prosecution/plaintiff and the defense in criminal and civil cases on issues related to biomechanics, particularly those involving head and neck injuries. My credentials in this area have never been challenged.

Head injury of neonates and infants has been and is being studied intensively at, for example, the University of Pennsylvania. Furthermore, head injury has been investigated scientifically since 1939 at Wayne State University, Detroit. The undersigned was honored as the pioneer who first brought biomechanics to the field of head injury in 1966¹ by being asked to present the plenary lecture at the 60th anniversary celebration of the 1939 commencement of the study of cervical trauma². Biomechanics is an integral and substantial part of bioengineering³. The undersigned and a colleague initiated a Joint Program in Bioengineering between the University of California Medical School in San Francisco and the College of Engineering at Berkeley. Today, four campuses of the University of California have Departments of Bioengineering, including that at San Diego. Most of the major institutions of higher learning in the United States created either similar departments, or have groups or programs in this highly respected field. There are at least two American archival journals devoted exclusively to this topic: the Journal of Biomechanics and the Journal of Biomechanical Engineering, the latter published by the American Society of Mechanical Engineers; many others devote a portion of their content to this subject. One of the twelve divisions of the National Academy of Engineering, which is the advisor to the American government in engineering matters and in which membership is considered to be the highest honor an American engineer can achieve, has a Division of Bioengineering.

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Biomechanics is the science of the application of the laws of mechanics, or physics, to biological systems and, in cooperation with certain members of the medical community, has made major contributions to an understanding of the physical processes involved in health science applications; for example, the use of prosthetic devices evolved from such collaboration, as has the development of protective gear for humans, such as motorcycle and bicycle helmets. Biomechanics can and has differentiated between different types and levels of force application, and, in particular, has addressed the question of how head injury is produced and how it can be mitigated.



7/12/00

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- 1 Goldsmith, Werner, "The Physical Processes producing Head Injury". In: *Head Injury Conference Proceedings*, ed. by W. F. Caveness, MD, and A. E. Walker, MD. Philadelphia, J. B. Lippincott, 350-382, 1966.
 (Invited paper for the conference which was organized and sponsored by the National Institute for Neurological Diseases and Stroke, NIH).
- 2 Goldsmith, Werner, "Past, Present and Future of Head Injury Biomechanics Research". Plenary Lecture. In: *Impact from Head to Foot, 60th Anniversary Proceedings*, Wayne State University, v. 1, 3-18, 1999
- 3 *Introduction to Bioengineering*, ed. by S. A. Berger, W. Goldsmith, E. S. Lewis. Chapter 1: Biomechanics of Solids, by W. Goldsmith. Oxford, Oxford University Press, 1-100, 1996, 2000.

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P.S. It is relevant to this document that my doctoral student and I are performing the first ever experiments on the failure strength of cerebral vessels from living humans, harvested with appropriate consent from epilepsy operations. A portion of this work has been invited for presentation at the forthcoming Winter Annual Meeting of the American Society of Mechanical Engineers in their Biomechanics Division.

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COMMENT & NOTE: Shaken Baby Syndrome: A Questionable Scientific Syndrome and a
Dangerous Legal Concept

Genie Lyons

SUMMARY:

Shaken baby syndrome in its most extreme form - assuming abuse when a child has two specific brain injuries but no other signs of trauma - quite possibly does not exist. Other countries aren't so quick to find abuse where there are no external indicia: Eva Lai Wah Fung, a Hong Kong researcher writing in *Pediatrics International*, states, "Retinal hemorrhage and subdural hematoma without external signs of injury in Japan [and Hong Kong] is usually attributed to accidental, trivial head injury, whereas subdural hemorrhage associated with external signs of trauma to the face or head were commonly found in cases of genuine child abuse. In spite of the many scientific studies that uncritically accept the existence of SBS, an adequate link between shaking a baby and the two SBS markers has never been scientifically verified and the latest evidence points strongly to organic reasons for the babies' distress, as opposed to shaking. Courts should admit, under Daubert, that evidence showing that the two classic medical signs used to show that a child had been deliberately shaken to the point of injury or death (subdural hematoma and retinal hemorrhaging in a child) is insufficient proof that a crime has been committed.

HIGHLIGHT: The problem isn't what we don't know.

The problem is what we do know that isn't so (1).

TEXT:

I. Introduction

Shaken baby syndrome in its most extreme form - assuming abuse when a child has two specific brain injuries but no other signs of trauma - quite possibly does not exist. An estimated 1,070,000 children were victims of abuse and neglect in 1999 (2). Of those, shaken baby syndrome is said to have injured or killed thousands (3). Even though the syndrome is almost universally accepted, the scientific underpinnings are surprisingly weak. Furthermore, recent

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findings point toward apnea (the baby stops breathing) - not deliberate harm - as the cause of the injury.

Since 1974, when shaken baby syndrome was first described (4) many caretakers have been convicted of violently shaking a baby to death. When there were no other signs of abuse, if a baby was found to be suffering with two symptoms - bleeding on the brain (subdural or subarachnoid hematoma) and bleeding behind the eyes (retinal hemorrhaging) - it was sufficient for conviction.

However, recent research, examined in this Note, casts doubt on the presupposition that the presence of SBS in a baby indicates that the baby was abused.

Under the existing test for admission of expert testimony into court, evidence of SBS does not show that a crime has been committed, and thus should not be used as grounds for criminal liability without other corroborating evidence.

A. Defining Shaken Baby Syndrome

SBS, as widely reported in the medical, legal, and public spheres is generally described as having the following features:

Caretakers may misrepresent or claim to have no knowledge of the cause of the brain injury. Externally visible injuries are often absent.

The act of shaking leading to shaken baby syndrome is so violent that individuals observing it would recognize it as dangerous and likely to kill the child. Shaken baby syndrome injuries are the result of violent trauma.

Serious injuries in infants, particularly those that result in death, are rarely accidental unless there is another clear explanation, such as trauma from a motor vehicle crash (5).

Consistent with the attitudes shown in the above quotes, if the medical and legal communities find SBS present in a child, the nearest adult is said to have deliberately and maliciously hurt that child (with all the concomitant legal implications) if the child is found to have subdural or subarachnoid hematoma and retinal hemorrhaging even when there are no other symptoms of abuse, such as finger marks, skull fractures, bruising at the back of the neck, indications of earlier injuries, and so on.

B. Medical Definitions of Shaken Baby Syndrome

1. Subdural and Subarachnoid Hematoma

The brain has three membranes surrounding it: an outer layer, called the dura matter, a middle layer, called the arachnoid, and a thin inner layer, called the pia matter (6). A subdural hematoma is bleeding between the dura and the arachnoid (7). An arachnoid hemorrhage is

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bleeding between the arachnoid layer and the pia matter (8). Adults experience two types of hematomas. An acute hematoma can be caused by a fall or a sudden blow, while a chronic hematoma can develop slowly over a period of weeks or months (9). Acute hematomas have severe symptoms such as loss of consciousness, severe headache, weakness on one side of the body, seizures, and changes in vision (10). Chronic subdural hematomas, in contrast, produce less-severe symptoms such as: mild headache; nausea or vomiting; change in personality; and weakness, numbness, or tingling in the arms and the legs (11).

Subdural and arachnoid hematomas as diagnosed in SBS are said to be produced by rotational forces that shear blood vessels as the brain is shaken and battered against the skull (12). These hematomas can also be produced by natural causes such as a ruptured berry aneurism (13), congenital bleeding problems (14), osteogenesis imperfecta (brittle-bone disease), external hydrocephalus (water on the brain), and rebleed of prior hematoma (15). Some researchers suggest that vaccine reactions could also cause the symptoms of SBS (16). Recent medical research shows that lack of oxygen to the brain can, by itself, cause subdural hematoma (17).

2. Retinal Hemorrhaging

Besides hematoma, the only other physical evidence for a diagnosis of SBS required by most courts is retinal hemorrhaging (18). The presence of such hemorrhaging is often seen as a marker of abuse (19). Such hemorrhages "are greatly overrepresented among cases of nonaccidental trauma in young children," (20) with incidence found between 50 and 100% of the time in injuries deemed non-accidental (21). But full-term babies delivered vaginally often have similar hemorrhages to those found in SBS, though they often disappear within a week (22).

C. The Size of the Child-Abuse Problem

Fifteen out of every hundred children are said to suffer abuse in a year (23). Seventy-six percent were under five, with 40% under a year old (24). Of those abused, 18% suffered from physical abuse: about 192,600 children (25). In 1999, 1,108 children died because of abuse (26). The number of children affected by SBS is not so clear. Commentators estimate that an immense number of children, up to 50,000 a year, are harmed by shaking (27), with up to a quarter of the children dying as a result (28). This number, however, is wildly inflated. The number 50,000 represents the total number of children who die of all causes in any year (29). If a quarter of the shaken babies die, that would be a total of 12,500 deaths per year, more than ten times the number that are killed from abuse by all causes. The improbable numbers given would support the conclusion that emotional issues surrounding SBS are getting in the way of clear thinking, even in trained scientific populations.

Exact SBS numbers are difficult to calculate, but one nationwide study found a total of 523 deaths from 1994 to early 1998 (based on a 42% return rate on surveys) (30). Scaling the number up (multiplying 523 by 1.58) yields around 825 deaths total, which works out (roughly) to about 206 deaths per year nationwide (31). With regard to prosecutions, a recent Westlaw search reports eighty-four cases in the United States in 2002 that concerned SBS.

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D. Legal Ramifications of a Diagnosis of SBS

A medical finding that a baby has the two markers for SBS often leads to dire consequences for the caregiver, even with no other finding or even suspicion of abuse.

In *People v. Rader* (32) a father was convicted of aggravated battery of a child when he confessed to slapping and shaking the baby in an attempt to revive it after it stopped breathing (33). The father also confessed to slapping the child across the face twice, and even though the court took this as a sign of abuse (34) the father's testimony was that he was trying to revive the child (35). He was convicted on the theory that the injuries were so severe they could only have been caused by violent shaking (36) and he was sentenced to twelve years in prison (37).

In another case, *People v. Wong* (38) both caretakers were convicted of second-degree manslaughter and endangering the welfare of a child when their baby died and was diagnosed with the two SBS markers (39). Mr. Wong was convicted of shaking the baby to death, and Mrs. Wong was convicted of letting the death happen, under the theory that she must have been "personally aware that the shaking had occurred." (40). Here, as in *Rader*, the court mentioned no other signs of abuse, and they assumed that a brutal homicide must have happened based solely on the evidence of "ruptured blood vessels." (41) As the record states:

"An autopsy performed on the child revealed that he had died as a result of internal brain injuries, including ruptured blood vessels, that could only be attributed to "shaken baby syndrome." That condition occurs when an infant under the age of one is subjected to violent shaking causing his or her head to snap back and forth. Under those conditions, the infant's brain, which is very soft, will move around inside the head, leading to ruptured blood vessels, hemorrhaging and swelling (42).

The *Wong* court uncritically accepted the standard definition of SBS, where it might have required more evidence if the parties involved had a better understanding of the underlying scientific debates.

This Note first examines the evidentiary standard required to present scientific information as defined by the U.S. Supreme Court in *Daubert v. Merrill Dow Pharmaceuticals, Inc.* (43). It then reviews the current scientific literature on SBS, and finally, it concludes that SBS in its current form should not be accepted by courts as good science. Rather, SBS should be seen as scientifically unproven and insufficient, standing alone, to be the legal basis for proving that a crime has been committed.

II. The Evidentiary Standard Under Daubert

A. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*

Federal Rule of Evidence 702 gives the standard for presenting scientific evidence in court (44). The main Supreme Court case that interprets this rule, *Daubert*, informs courts that they must make an independent inquiry into the validity of any scientific testimony presented. *Daubert* asks

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the courts to make a determination of "whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue." (45).

Four factors are outlined, and a fifth suggested, for judges to use when determining if proposed testimony crosses the scientific threshold (46). Each is discussed below.

1. Can and Has the Theory Been Tested?

The first (and most confusing) factor is "whether a theory or technique ... can be (and has been) tested." (47) Quoting the philosopher of science Karl Popper, the Court stated, "the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability." (48) This actually poses two separate questions: (1) Can the theory be falsified in the Popperian sense? (2) Has the theory been sufficiently tested? Each question will be discussed in turn.

a. Is the Theory Falsifiable?

According to Popper, "the work of the scientist consists in putting forward and testing theories." (49). Scientists make a guess (a theory) and then test that guess to see if it comports with reality. Not all guesses count as scientific, though. A guess must be capable of disproof: there must be some identifiable fact that - if true - would disprove the theory. That is, the theory can be proven or disproven by looking at empirical evidence. Popper himself says, "[A] theory is falsifiable if the class of its potential falsifiers is not empty." (50). Popper gives the example that "to falsify the statement 'All ravens are black' the inter-subjectively testable statement that there is a family of white ravens in the zoo at New York would suffice." (51).

However, a scientific guess is not upgraded to a scientific theory until it has garnered experimental or observational support (52). Even as a theory it is still tentative, always susceptible to falsification.

If something is unfalsifiable, it doesn't mean that it's not true, just that it's not strictly scientific. A classic unfalsifiable phrase is "God moves in mysterious ways." There is no experiment that could be devised to disprove such a statement. Paradoxically, such unfalsifiable theories appear to have greater explanatory power than those that are testable (53). For example, creation science, an unfalsifiable theory, (54) contemplates the origins and the ultimate meaning of life - topics that are outside the scope of scientific proof (55).

b. Has the Theory Been Falsified?

Once a theory has been found to be scientific, the next question is whether it has been falsified or corroborated by observations or experiments. That is, has the theory been verified? Confusing the second Daubert criterion (whether the theory has been falsified through experimentation) with the first (is this idea sufficiently scientific in the first place) is a serious mistake, as it changes the question from analyzing the essential nature of the theory (correct) to looking at the current state of the data on the theory (incorrect) (56). This is a subtle point (57) but an

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extremely important one, because it marks the boundary between objective science, which belongs in the courtroom, and inexact belief, which does not.

In particular, a scientific theory may be disproven by a single journal article, no matter how many other articles have been published that agree with it. One view of Earth from space is enough to disprove the flat-earth theory, no matter how many people warn that you will fall off the edge if you travel too far.

2. Has the Theory Been Peer-Reviewed?

The second Daubert factor is whether, and to what extent, the theory has been published in peer-reviewed journals. "The fact of publication (or lack thereof) in a peer reviewed journal thus will be a relevant, though not dispositive, consideration in assessing the scientific validity of a particular technique or methodology on which an opinion is premised." (58)

3. What Is the Rate of Error?

Third, the Daubert Court looks at rate of error. "Additionally, in the case of a particular scientific technique, the court ordinarily should consider the known or potential rate of error...." (59)

4. What Is the Acceptance Level?

Fourth, the degree of acceptance in the scientific community can be considered. A "reliability assessment does not require, although it does permit, explicit identification of a relevant scientific community and an express determination of a particular degree of acceptance within that community." (60). However, "general acceptance is not a necessary precondition to the admissibility of scientific evidence under the Federal Rules of Evidence." (61).

5. Flexibility Concerns

Finally, the Court emphasizes the flexibility of the inquiry, whose "overarching subject is the scientific validity - and thus the evidentiary relevance and reliability - of the principles that underlie a proposed submission. The focus, of course, must be solely on principles and methodology, not on the conclusions that they generate." (62). This implicitly recognizes that scientific truths are conditional, and new results, as long as they are reached by appropriate methodologies, should not be discarded simply because they are controversial.

The Court blurred this rule a bit in *General Electric Co. v. Joiner* (63) when it stated that "conclusions and methodology are not entirely distinct from one another." (64). However, as it later stated that "[a] court may conclude that there is simply too great an analytical gap between the data and the opinion proffered," (65) it seems clear that the *Joiner* Court's opinion was that good data alone will not bless scientific testimony with enough reliability to leap over the Daubert threshold. The data must also be accompanied by reasonable conclusions.

B. *Kumho Tire Co. v. Carmichael* (66)

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The Daubert Court left open the question of whether the Daubert factors should be applied to nonscientific testimony. Two competing views arose: one held that the Daubert factors should be applied to all reliability testimony, while the other held that the pre-Daubert application of Rule 702 still stood for testimony that wasn't strictly scientific. (67).

In *Kumho Tire*, the Court concluded "that Daubert's general holding - setting forth the trial judge's general 'gatekeeping' obligation - applies not only to testimony based on 'scientific' knowledge, but also to testimony based on 'technical' and 'other specialized' knowledge." (68). The Court, however, took great pains to emphasize the flexibility of the analysis, stating that the list of factors in Daubert was "meant to be helpful, not definitive," (69) and that the specific criteria used "must be tied to the facts of a particular case." (70).

III. The Science Behind Shaken Baby Syndrome

A. History

In the landmark 1962 paper *The Battered-Child Syndrome* (71), C. Henry Kempe described a constellation of symptoms in children that were most likely caused by abuse rather than accident, as had been previously assumed. These included outward physical indicia of abuse such as poor skin hygiene, multiple soft-tissue injuries, malnutrition, fractures (especially those of different ages indicating ongoing abuse), and "a history of previous episodes suggestive of parental neglect or trauma." (72). Internal indicia such as subdural hematoma is also mentioned as "an extremely frequent finding." (73). This article brought the problem of abused children to the forefront of American society, and it intensified the role of the physician as a first-line defense against child abuse (74).

Expanding on the earlier work, John Caffey in 1974 suggested that babies could be seriously injured with no external signs of trauma to the body (75). Rather, a finding of subdural hematoma and intraocular hemorrhages was sufficient to determine abuse (76). Although Caffey posited a mechanism for the syndrome, the delicate infant head striking the chest and back (77), he admitted that his "current evidence [was] manifestly incomplete and largely circumstantial." (78).

B. Early Proof

In 1987, a biomechanical study was undertaken by Ann-Christine Duhaime and others to discover what forces affected babies' heads when they were shaken (79). Carefully designed models of infant heads were equipped with accelerometers and then shaken. The gathered data were then compared with known primate-shaking data. The comparison showed that shaking alone (the method postulated by Caffey) produced less than one quarter of the force necessary to produce the SBS markers of subdural hematoma and retinal hemorrhaging in primate models (80). A force fifty times greater than shaking was produced by the sudden deceleration when the model was thrown against an object (81). The authors concluded that shaking didn't produce the

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SBS markers, but hedged their language: "It is our conclusion that the shaken baby syndrome, at least in its most severe acute form, is not usually caused by shaking alone." (82). They suggested that the term "shaken impact syndrome" be used instead (83).

The authors stated in conclusion that "unless a child has predisposing factors..., fatal cases of the shaken baby syndrome are not likely to occur from the shaking that occurs during play, feeding, or in a swing, or even from the more vigorous shaking given by a caretaker as a means of discipline." (84). Indeed, shaking itself (with a force of 9.29 Gs) was shown by the study not to cause the injuries at all (85). Rather the injuries were caused by the impact acceleration (with a force 428.18 Gs) when the model slammed into a metal bar or a padded surface (86).

A 1989 study by Mark Hadley (87) came to the opposite conclusion, saying that "direct cranial trauma is not an essential element of the injury mechanism in young patients who sustain severe whiplash-shake injuries." (88). The Hadley study examined thirty-six infants with head injuries (89). Thirteen of these patients had no "direct cranial trauma," but had both retinal hemorrhaging and either subarachnoid or subdural hemorrhaging (90). This was seen as proof that the children had "a history of whiplash-shake injury without direct impact trauma" even though "doubt remains about the true mechanism of these injuries." (91). This is circular reasoning. There is nothing in the record saying that the babies were shaken; the authors are simply assuming their conclusion.

This point is made by a Hong Kong researcher (whose paper on the restricted definition of child abuse in the Far East is referenced later), who mentions the circular reasoning at the heart of the western SBS definition:

If all members of the [child abuse] team are "educated" to the fact that the presence of subdural hematoma and/or retinal hemorrhage with "no history accounting for patient's serious head injury," is diagnostic of child abuse, then all cases will increasingly be so classified irrespective of what the caregivers say. For some this may mean a lengthy term in jail (92).

Another study by Duhaime, published in 1992, looked at both accidental and inflicted head injuries in children younger than two to help determine which specific markers were indicia of abuse (93). However, the presence of a hematoma with "changing history or developmentally incompatible history" was considered presumptive proof of abuse (94). The authors found that nearly a full quarter of the children with head injuries met their criteria for intentional infliction (95). However, as (1) possessing an intracranial hemorrhage with (2) a "history insufficient to explain injuries" was considered a primary marker of abuse (96), they were using inclusion criteria to define the conclusion: circular reasoning - a methodological flaw.

Interestingly, though in the body of the paper the authors say that "retinal hemorrhages can occur under a variety of circumstances," (97) in the conclusion they say, "retinal hemorrhages are highly associated with inflicted injuries in very young children...." (98). Again, the inclusion criterion of retinal hemorrhaging is being used to justify its presence (99).

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Duhaime updated her findings in a 1998 paper in the New England Journal of Medicine (100). Though she mentioned that "the causes of the severe brain swelling and subsequent extreme tissue loss in infants with the shaking-impact syndrome who survive are incompletely understood," (101) she goes on to state that subdural and subarachnoid blood is the most common finding and "a marker for the threshold of force required to cause the injury." (102). Again, a circular definition is used to determine when injuries are non-accidental, which includes a history of no or little trauma and the presence of subdural hematoma (103).

The Caffey markers, bleeding in the brain and retinal hemorrhaging, standing alone, are now almost universally seen as proof of SBS - that the baby was deliberately harmed by a much larger, malevolent caretaker (104). This view has also been adopted by the legal community. For example, in 1999 the Indiana Legislature adopted a definition of "shaken baby syndrome" that requires bleeding inside the head and one of twelve other symptoms, including subdural hematoma (bleeding inside the head) and retinal hemorrhage (105). Courts also try and convict people under this medical hypothesis (106). However, new research casts doubt on the scientific basis of the theory.

C. Current Findings

A paper recently published in the British Journal of Neurosurgery by R. Uscinski calls into doubt the original Caffey study (107). It points out that the only study offered in Caffey as experimental verification of SBS as a cause of traumatic injury in babies actually looked at whiplash injury incurred in simulations of rear-end vehicle collisions (108). No shaking was involved (109). Rather, the conclusions of the work cited by Caffey were that severe whiplash (110) caused head injuries (111). The 1987 Duhaime study cited earlier showed that humans could only shake with enough force to produce one quarter of the "predicted concussive injury thresholds" (112) meaning that shaking as a cause of injury has no theoretical basis, although hurling a child will do much damage. Furthermore, "subdurals in infants can occur after apparently normal birth, and a true incidence (and prevalence) of birth related subdural bleeding has yet to be determined. [A child with such bleeding could] present clinically weeks or even months later with a chronic subdural haematoma" (113). This child would fit the current definition of SBS even if it had never been shaken. Uscinski also points out that prior to 1972 retinal hemorrhaging "was a diagnostic aid in detecting the presence of chronic subdural haematoma in children." (114). So, rather than being an independent marker of abuse, retinal hemorrhaging might simply be a result of an underlying subdural hematoma.

Other countries aren't so quick to find abuse where there are no external indicia: Eva Lai Wah Fung, a Hong Kong researcher writing in *Pediatrics International*, states, "Retinal hemorrhage and subdural hematoma without external signs of injury in Japan [and Hong Kong] is usually attributed to accidental, trivial head injury, whereas subdural hemorrhage associated with external signs of trauma to the face or head were commonly found in cases of genuine child abuse." (115). By studying brain injuries in piglets, other researchers have discovered that infant brains were no more susceptible to traumatic brain injury than adult brains (116).

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Perhaps the most informative study to date, by J.F. Geddes and others, is one that examined "37 infants aged 9 months or less, all of whom died from inflicted head injuries." (117). It shows, by careful microscopic examination of infant brains said to have died from SBS, that they do not have the damage at the cellular level that would indicate trauma caused by shaking or by shaking and throwing (118). Not only does shaking not cause SBS, but neither does shaking and then tossing: the shaken-impact syndrome.

The study states, "Seen from this point of view, the debate over shaken versus shaken-impact becomes irrelevant, and because there is no DAI [diffuse axonal injury] it is possible that the severe acceleration-deceleration injury that is so often cited does not in fact occur in shaken-baby syndrome." (119).

Furthermore, the study shows that apnea (cessation of breathing) causes the SBS markers (120). In the court cases cited previously (and many others) (121), the accused said that they shook the babies because they weren't breathing. These authors say we should believe them. "While one might tend to dismiss the statements of carers in child abuse cases, the story of respiratory abnormalities or apnea recurs with great regularity in the clinical notes of the infants." (122). This finding is one of many in the text of the article, but is highlighted in an accompanying editorial, which strongly implies that lack of oxygen alone may be enough to cause the observed injuries (123).

The authors posited a reason for the apnea. Eleven of the infants had damage to a regulatory area of the brainstem that controls breathing (124). The authors hypothesized that this area could be easily damaged by shaking, and that the damage then causes apnea (125). However, twenty-three of the thirty-seven babies had no signs of such damage to their brainstems, and their deaths are not otherwise explained (126). One is left with the reasonable inference that their brain swelling was caused by apnea alone, or at least by apnea combined with some cause other than shaking.

A related study in the same issue of *Brain*, by the same authors, looked at fifty-three cases of non-accidental head injury (127). Researchers looked for microscopic evidence of impact (diffuse axonal trauma), but found it in only two infant cases, both of whom also had severe head injuries (128). However, global hypoxia (insufficient oxygen to the brain) was found in 84% of the infant cases (129). This indicates that the brain was not damaged by shaking (130). Retinal hemorrhaging was "seen both in cases in which impact had occurred, and in cases in which there was no macroscopic evidence of impact. There was, however, a statistically significant association between subdural and retinal bleeding." (131). In layperson's terms, if there's bleeding on the brain, there is often bleeding behind the eyes as well.

Two ophthalmologists summing up the current state of research stated, "The actual existence of SBS as a pure pathologic entity unassociated with blunt force head trauma must be seriously questioned." (132). "If one thing is clear now, it is that we do not understand the pathophysiology of infant brain injury nearly as well as we thought." (133).

IV. Examining Shaken Baby Syndrome Testimony in Light of the Daubert Factors

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A. Can the Theory Be Tested, and Has It Been Tested?

1. *Is the Diagnosis of SBS as It Currently Stands Falsifiable?*

A logical circularity resides at the heart of most SBS studies. One of the main diagnostic findings leading to an SBS diagnosis is the absence of any other signs that abuse has occurred. The original Caffey study said: "The absence of a history of trauma of any kind in 54% [of children diagnosed with shaken-whiplash syndrome] is significant and suggests that whiplash shaking may be the cause in many patients." (134). In other words, if there is no other cause at all then we assume whiplash from shaking. Non-accidental head injury was likewise presumed in a 1999 study if a child had intradural hemorrhages (bleeding on the brain) and "history insufficient to explain injuries." (135).

Similarly, the Hadley article discussed supra, widely cited for the proposition that no direct trauma is necessary for a finding of SBS, has similar language worth quoting. It too says that finding no trauma (that is, no sign of abuse) is prima facie proof that such abuse occurred:

"Our data do not conclusively demonstrate that severe neurological trauma can occur with rapid, forceful, repetitive acceleration-deceleration of the head and neck with respect to the torso. Because most of these assaults are not witnessed, doubt remains about the true mechanism of these injuries. However, to the best of our abilities and those of the other professionals investigating these cases, we were able to document that each of the 13 patients had a history of whiplash-shake injury without direct impact trauma. Supporting the history in each case is the fact that none of the patients had clinical signs or radiographic evidence of craniofacial trauma." (136).

This conflicts strongly with the major forces that are said to be necessary to produce such symptoms, "The act of shaking ... is so violent that [untrained] individuals observing it would recognize it as dangerous." (137). Other related causes of childhood trauma, which differ from SBS mainly because of the greater degree of visible harm to the child, do not show subdural hematoma and retinal hemorrhage.

It is striking to see just how few cases of RH [retinal hemorrhaging] occur after TA [traffic accidents] when one considers the magnitude of energy transfers involved, compared to the relative weakness of irate caretakers. RH is also less common in the child-beating syndrome than in SBS, and is not part of the so-called "projectile child syndrome." This suggests that the violence of trauma by itself is not enough to cause RH in SBS; rotational trauma and repeated shaking are probably key features leading to RH in SBS, although the striking similarity between RH in SBS and in aneurysmal bleeding suggests some common, as yet unknown, mechanism (138).

To put this in layperson's terms: if a baby has visible signs of harm that indicate battering or being thrown, they have a much lesser chance of having the two markers for SBS (subdural hematoma and retinal hemorrhaging), which are themselves supposed to indicate even more severe abuse but which mysteriously leave no visible marks.

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If not possessing a symptom (that would be expected to be seen) is proof that the syndrome occurs, then the argument is circular, (as the effect and the cause are the same thing) (139) and unfalsifiable in the Popperian sense, because there is no way to disprove the theory that shaking causes SBS.

2. Has SBS Been Satisfactorily Tested?

In spite of the many scientific studies that uncritically accept the existence of SBS, an adequate link between shaking a baby and the two SBS markers has never been scientifically verified and the latest evidence points strongly to organic reasons for the babies' distress, as opposed to shaking. Studies show:

- a. Retinal hemorrhaging is not a marker of shaking a baby (140).
- b. Babies with the SBS markers rarely show signs of trauma predicted by the theory (141).
- c. Shaking does not produce enough force to cause the hemorrhaging and hematoma (142).
- d. Babies diagnosed with SBS do not show signs of having physical trauma to their brains (143).
- e. Apnea causes the same symptoms - bleeding on the brain and behind the eyes - as those relied on for a diagnosis of SBS (144).

The scientific basis for SBS is itself very shaky.

B. Has the Diagnosis of SBS Been Published in Peer-Reviewed Journals?

There have been many studies of SBS appearing in the most reputable of journals. However, the findings are open to question, with the later studies tending to narrow or disprove the earlier ones. The Daubert Court says that "submission to the scrutiny of the scientific community is a component of 'good science,' in part because it increases the likelihood that substantive flaws in methodology will be detected." (145). That is exactly what has happened here, with the "substantive flaws" in the methodology coming to light through recent application of the scientific process.

C. What Is the Error Rate?

The current theory of SBS has serious error-rate problems, as acknowledged by the scientific authors. Rarely is child abuse admitted in these cases, rather it is assumed if the SBS markers are present, as has been previously discussed. Therefore, the error rate is entirely unknown. This problem was clearly explicated in a letter published in 2001 in the American Journal of Forensic Medicine:

In this field [SBS research] more than others we are more readily prone to alter the facts to fit the hypothesis rather than alter the hypothesis to fit the facts. For example, if the accused admits to severely harming the child, we tend to believe because this fits our hypothesis, but if the accused offers an alternative apparently innocuous explanation we discount the explanation because it doesn't fit the hypothesis. Published cases purporting to demonstrate less traumatic causes are

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attacked for their anecdotal data and for overlooking the real, more sinister explanation. This "illogical inconsistency" overlooks scientific process and forgets that the requirement for severe shaking forces is no more than a favored but unproven hypothesis (146).

But the problem is even worse because often the slightest admission that a baby was shaken is seen as admitting abuse. When a baby stops breathing, it is natural to jostle or even shake the baby to wake it up. When caregivers are interviewed by police, they often mention this shaking, which is then taken as an admission that (1) abuse occurred, and (2) the abuse was the cause of the injuries. For example, the defendant Jones, in *Jones v. State* (147) admitted to shaking a baby several times "trying to get the child to breathe" after the child was dropped and stopped breathing (148). The prosecutor interpreted this at trial as Jones having "freaked out," "lost it," and that he "went into a rage" when he shook the child (149). Jones was convicted of felony murder, among other charges (150).

Similarly, the defendant in *State v. Mascarenas* (151) confessed to shaking a very fussy baby hard once (152). The court took that as an admission of guilt (153), and he was convicted of and sentenced to twelve years for negligent child abuse resulting in death (154).

However, research for this Note uncovered no studies showing that cases of child abuse can be separated from other accidental or medical reasons for harm. Medical evidence is accumulating that other reasons for the possible harm, previously disregarded, should be given weight. If a caretaker says that a baby's injuries were caused by a fall from a low height, they are assumed to be lying. Courts and medical authorities often state uncategorically that a fall would have to occur from the top of at least a two-story building to cause the SBS symptoms (155). However, a study published in 2001 indicates that a "fall from less than 3 meters (10 feet) ... may cause fatal head injury and may not cause immediate symptoms," (156) with the injury including the classic SBS pattern of retinal hemorrhaging and subdural hematoma. Eighteen observed deadly falls by children from heights varying from two to ten feet were examined (157). Thirteen of the children had subdural hematoma, five had skull fractures, and four (of only six examined for eye injuries) had retinal hemorrhaging (158). Furthermore, twelve of the children had a lucid interval before expiring (159).

Evidence of earlier head injuries is often used by medical personnel and courts to indicate a pattern of abuse. However, recent findings question such techniques, suggesting instead that a single recent injury can give the appearance of both old and new injuries (160).

There is much uncertainty surrounding the error rate in SBS, starting with the circularity of defining the symptoms as proof of the problem, and continuing with the problem that modest falls can cause the symptoms despite protests to the contrary. There is nothing approaching proof beyond a reasonable doubt that shaking is even involved (161). The error rate is much too high to allow the current definition of SBS to be presented to courts as a reliable scientific finding.

D. Does the Theory Have General Acceptance?

SBS does have general acceptance in both the medical and the legal community. However, this doesn't mean that the theory is correct, as was understood by the Court. The Daubert Court

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overturned the earlier Frye standard, which stated that "expert opinion based on a scientific technique is inadmissible unless the technique is "generally accepted" as reliable in the relevant scientific community." (162). In *Daubert*, Merrill Dow, the respondent, presented evidence that its theory (that anti-nausea medication Bendectin did not cause birth defects) was overwhelmingly accepted by the courts and the scientific community (163). However, respondents did not even attempt to show that the methods used by the petitioners to show a causal link between Bendectin use and birth defects were incorrect, just that the answers arrived at by the plaintiff's scientists were different than that given by earlier research (164). The Court in *Daubert* refused to disallow the petitioner's less accepted but methodologically acceptable testimony based on the Frye standard (165).

Similarly, the fact that many courts have accepted the standard SBS definition should not be an obstacle preventing the new scientific data from being presented in court. Respect for precedent does not require courts to ignore flaws in logic. The law must adapt when prior scientific theories are undermined by further scientific advances. In law, precedent is respected. Older results get more deference. The reverse is true in science, where older scientific theories are modified or discarded by new scientific advances. Respect for precedent in law should not be followed when the law is interpreting scientific evidence.

V. Conclusion

For many years now, attorneys have been willing to prosecute, and juries have been willing to convict, people whose only clearly established mistake was caring for a baby that died. Considering the confused state of the medical evidence surrounding SBS, especially since it appears that shaking cannot harm a baby in the manner that has been described for the last thirty years, we should return to the standard proposed in 1962 (166). That is, people should not be accused of child abuse on the basis of subdural hematoma and retinal hemorrhaging alone. Courts should admit, under *Daubert*, that evidence showing that the two classic medical signs used to show that a child had been deliberately shaken to the point of injury or death (subdural hematoma and retinal hemorrhaging in a child) is insufficient proof that a crime has been committed.

It should be acknowledged that although shaking a baby is never a good idea, innocent light shaking alone, without some other sign of intentional abuse, does not produce the SBS symptoms. Confession to shaking a baby after it stops breathing (an understandable last resort in dire circumstances) should never be used as an admission of guilt. Rather, child abuse should only be assumed as a last resort: if other indicia of abuse are present such as long-bone injuries, a fractured skull, bruising, or other indications that abuse has actually occurred. Sometimes children just die, and there is no one to blame.

FOOTNOTES:

1. This quotation is often attributed to either Mark Twain or Will Rogers, but was actually coined by Josh Billings, nineteenth century humorist. Mark Twain, *Misattributed Quotes: What Mark Twain Didn't Say*, n.6 (Jim Zwick, ed.) at

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- [http://www.boondocksnet.com/twaintexts/quotes not twain.html](http://www.boondocksnet.com/twaintexts/quotes%20not%20twain.html) (last visited Oct. 10, 2003).
2. Nancy Peddle & Ching-Tung Wang, Current Trends in Child Abuse Prevention, Reporting, and Fatalities: The 1999 Fifty-State Survey - Working Paper no. 808, at 17 (National Center on Child Abuse Prevention Research, Aug. 28, 2001).
 3. Susan Linn & Alvin F. Poussaint, Fragile: Handle with Care, *Newsweek*, Spring/Summer 1997, at 33.
 4. John Caffey, The Whiplash Shaken Infant Syndrome: Manual Shaking by the Extremities With Whiplash-Induced Intracranial and Intraocular Bleedings, Linked With Residual Permanent Brain Damage and Mental Retardation, 54 *Pediatrics* 396 (1974).
 5. American Academy of Pediatrics, Shaken Baby Syndrome: Rotational Cranial Injuries - Technical Report, 108 *Pediatrics* 206, 206 (2001).
 6. Intellihealth, Subdural Hematoma, at <http://www.intelihealth.com/TH/ihTH/WSIHW000/9339/9621.html>.
 7. *Id.*
 8. *Id.*
 9. *Id.*
 10. *Id.*
 11. *Id.*
 12. Caffey, *supra* note 4, at 401.
 13. See Joseph A. Prahlow et al., Death Due to a Ruptured Berry Aneurysm in a 3.5-Year-Old Child, 19 *Am. J. Forensic Med. & Pathology* 391, 391 (1998).
 14. See Richard S. Newman et al., Factor XIII Deficiency Mistaken for Battered Child Syndrome: Case of "Correct" Test Ordering Negated by a Commonly Accepted Qualitative Test With Limited Negative Predictive Value, 71 *Am. J. Hematology* 328, 328 (2002).
 15. J. Kirk Osborn, Meeting the State's Medical Case in "Battered Child Cases," 23 *True Bill*, Nov. 2002, at 4, 5-6.
 16. See, e.g., Jan Goodwin, Was It Murder, Or A Bad Vaccine?, *Redbook Mag.*, Sept. 2000, at 158, available at <http://www.whale.to/m/sbs21.html> (giving examples of doubtful diagnoses of SBS and proposing vaccination reaction as more likely explanation).
 17. J.F. Geddes et al., Neuropathology of Inflicted Head Injury in Children I: Patterns of brain damage, 124 *Brain* 1290, 1298 (2001) [hereinafter Geddes, Patterns of brain damage].
 18. Joseph D. Hatina, Shaken Baby Syndrome: Who are the True Experts?, 46 *Clev. St. L. Rev.* 557, 576 n.148 (1998). See also *infra* note 106 (discussing medical expert testimony in shaken-baby prosecutions).
 19. See Osborn, *supra* note 15, at 4.
 20. Mary E. Case et al., Position Paper on Fatal Abusive Head Injuries in Infants and Young Children, 22 *Am. J. Forensic Med. & Pathology* 112, 116 (2001).
 21. See Jane D. Kivlin, Manifestations of the Shaken Baby Syndrome, 12 *Current Opinion Ophthalmology* 158, 159 (2001).
 22. Case, *supra* note 20, at 116.
 23. See Peddle & Wang, *supra* note 2, at 6.
 24. *Id.* at 20.
 25. *Id.* at 6.

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26. *Id.* at 17. However, this number is said to be low because of misclassification. *Id.* at 16.
27. The 50,000 number is quoted without attribution in a wide variety of sources. For example, the American Association of Neurological Surgeons cites these statistics, in its position paper, Shaken Baby Syndrome - A Potentially Deadly Concern, found online in Medem Medical Library at http://www.medem.com/MedLB/article_detailb_for_printer.cfm?article_IDZ9G8DUE_8C&sub_cat=355. The New York City Administration for Children's Services also quotes 50,000 cases per year, while mentioning that only forty-four cases were seen in New York City between 1999 and 2001. Administration for Children's Services, Mayor Michael R. Bloomberg Marks Child Abuse Awareness Month With Public Education Campaign To Reduce Shaken Baby Syndrome, Apr. 23, 2002, at http://www.nyc.gov/html/acs/html/whatwedo/pr02_04_23.html.
28. United States Advisory Board on Child Abuse and Neglect, A Nation's Shame: Fatal Child Abuse and Neglect in the United States, at <http://ican-ncfr.org/shame/chapter1/data.html> (last visited Oct. 10, 2003).
29. National Center on Fatality Review, at <http://ican-ncfr.org>.
30. Child Abuse Prevention Center's National Information, Support and Referral Service on Shaken Baby Syndrome, National Study on Shaken Baby Syndrome Fatalities (Sept. 1988).
31. *Id.* Without assuming that these statistics accurately reflect the level of SBS diagnosis, they are noteworthy because they give a feel for the difference between the magnitude of the problem as sometimes presented (50,000 children/year) and as (imperfectly) documented (206 children/year).
32. *651 N.E.2d 258 (Ill. App. Ct. 1995)*.
33. *Id.* at 260-61.
34. *Id.*
35. See *id.*
36. *Id.* at 264.
37. *Id.* at 260.
38. *619 N.E.2d 337 (N.Y. 1993)*.
39. The conviction was reversed because of the jury's "impermissible speculation." *Id.* at 382.
40. *Id.*
41. *Id.* at 380.
42. *Id.*
43. *509 U.S. 579 (1993)*.
44. Rule 702 reads: If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.
45. *509 U.S. at 592-93*
46. A great deal of ink has been spilled discussing not only just what the Daubert Court meant, but also whether the underlying scientific view was valid. For a good overview of the debate see Jan Beyea & Daniel Berger, Scientific Misconceptions Among Daubert Gatekeepers, 64 Law & Contemp. Probs. 327, 360, for a discussion of "the two views of

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science - process versus formal-logic that are in tension in Daubert and successive opinions."

47. *Daubert*, 509 U.S. at 593.
48. Id. (quoting Karl R. Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* 37 (5th ed. 1989)).
49. Karl Popper, *Scientific Method* (1934) in *A Pocket Popper* 133 (David Miller ed., 1983).
50. Karl R. Popper, *The Logic of Scientific Discovery* 86 (Routledge 1997) (1959).
51. Id. at 87 n.1. See also David L. Faigman, *To Have And Have Not: Assessing The Value Of Social Science To The Law As Science And Policy*, 38 *Emory L.J.* 1005, 1017 (1989) (discussing difference between theory that is falsifiable and one that is not).
52. For an excellent description of the difference between theories that cross the scientific threshold and those that do not, see the *Amicus Curiae Brief Of 72 Nobel Laureates, 17 State Academies of Science, and 7 Other Scientific Organizations, In Support of Appellees, Edwards v. Aguillard*, 482 U.S. 578 (1987) (No. 85-1513), at 22-24.
53. See Faigman, *supra* note 51, at 1017.
54. *Edwards v. Aguillard*, 482 U.S. 578, 603-04 (1987) (holding creation science is religious belief rather than scientific theory because "the tenets of creation science parallel the Genesis story of creation, and this is a religious belief").
55. For a full discussion on the non-overlapping spheres of science and religion, see Stephen J. Gould, *Rock of Ages: Science and Religion in the Fullness of Life* 4 (1999). He states: "Science tries to document the factual character of the natural world, and to develop theories that coordinate and explain these facts. Religion, on the other hand, operates in the equally important, but utterly different, realm of human purposes, meanings, and values - subjects that the factual domain of science might illuminate but can never resolve."
56. The concept of falsifiability seems to have confused the legal community which, in both court opinions and commentary, have misinterpreted the concept as whether the theory has been corroborated by observations. See, e.g., *Cummins v. Lyle Indus.*, 93 F.3d 362, 368 (7th Cir. 1996) (equating falsifiability with experimentation: "The Supreme Court has articulated several nonexclusive guideposts to assist the district courts in determining whether expert testimony fairly can be characterized as a scientific opinion: (1) whether the proffered conclusion lends itself to verification by the scientific method through testing ..."); *United States v. Havvard*, 117 F. Supp. 2d 848, 852 (S.D. Ind. 2000) (confusing falsification with corroboration: "In the roughly 100 years since fingerprints have been used for identification purposes, no one has managed to falsify the claim of uniqueness by showing that fingers of two persons had identical fingerprints."); Gary Edmond & David Mercer, *Conjectures and Exhumations: Citations of History, Philosophy and Sociology of Science in US Federal Courts*, 14 *Law & Literature* 309, 316 (2002) ("The Daubert criteria were intentionally focused on testing - particularly whether an opinion had actually been tested - and the (positive) existence of published materials."); Sara K. Ledford, *The Implications of Kumho Tire: Applying Daubert Analysis to Warning-Label Testimony in Products Liability Cases*, 76 *Ind. L.J.* 465, 473 (2001) (equating falsifiability with testing). For an empirical finding of confusion among the legal profession, see Joseph Sanders et al., *Legal Perceptions of Science and Expert Knowledge*, 8 *Psychol. Pub. Pol'y & L.* 139, 152 (2002). Although over 90% of the judges seemed to

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understand the criteria of peer review/publication and general acceptance, their understanding of the other two criteria was poor. Only 6% of the judges gave answers that indicated a clear understanding of falsifiability. Only 4% indicated a clear understanding of error rates.

57. Chief Justice Rehnquist confessed himself at a loss here in his partial dissent in *Daubert*. He said, "I defer to no one in my confidence in federal judges; but I am at a loss to know what is meant when it is said that the scientific status of a theory depends on its 'falsifiability,' and I suspect some of them will be, too." *Daubert*, 509 U.S. at 600 (Rehnquist, C.J., concurring in part and dissenting in part).
58. *Daubert*, 509 U.S. at 594.
59. *Id.*
60. *Id.* (internal quotation marks omitted).
61. *Id.* at 597 (internal quotation marks omitted).
62. *Id.* at 594-95.
63. 522 U.S. 136 (1997).
64. *Id.* at 146.
65. *Id.*
66. 526 U.S. 137 (1999)
67. D. Michael Risinger, Defining the "Task at Hand": Non-Science Forensic Science After *Kumho Tire Co. v. Carmichael*, 57 Wash. & Lee L. Rev. 767, 769 (2000).
68. *Kumho Tire*, 526 U.S. at 141.
69. *Id.* at 151.
70. *Id.* at 150 (internal quotation marks omitted).
71. C. Henry Kempe et al., The Battered-Child Syndrome, 251 J. Am. Med. Assoc. 3288 (1984) (1962). This paper was groundbreaking in that it also stated what we now consider obvious, but was a revelation at the time, that "beating of children ... occurs among people with good education and stable financial and social background." *Id.* at 3289.
72. *Id.* at 3288-89.
73. *Id.* at 3288.
74. See Marilyn Heins, The "Battered Child" Revisited, 251 J. Am. Med. Assoc. 3295, 3295 (1984).
75. Caffey, *supra* note 4, at 397.
76. *Id.*
77. *Id.* at 401.
78. *Id.* at 403. Caffey explained the paradoxical nature of his findings: "The most characteristic pattern of physical findings in the whiplashed infant is the absence of external signs of trauma to the head and the soft tissues of the face and neck, and of the facial bones and calvaria, in the presence of massive traumatic intracranial and intraocular bleedings. This is an extraordinary diagnostic contradiction." *Id.* at 399.
79. Ann-Christine Duhaime et al., The Shaken Baby Syndrome: A Clinical, Pathological, and Biomechanical Study, 66 J. Neurosurgery 409 (1987) [hereinafter Duhaime, 1987].
80. *Id.* at 413 fig.2.
81. *Id.* The models were thrown against a metal bar and a padded surface. *Id.*
82. *Id.* at 414.

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83. *Id.* But see Robert Reece, *Medical Evidence in the Context of Child Abuse Litigation*, 36 *New Eng. L. Rev.* 607, 610 (2002) (stating that shaking versus shaking plus impact is not real controversy because "in all of these shaking cases there is acceleration at the end of the arc of the swing").
84. Duhaime, 1987, *supra* note 79, at 414.
85. *See id.*
86. *Id.* at 413-14. "Figure 2," which shows the force necessary to cause injury, is particularly informative, with all of the shake data clustered in the extreme lower-left-hand corner, far outside of the range to produce any injury. The impact data is scattered across the rest of the table, showing enough force to produce concussion, subdural hematoma, and diffuse axonal injury (severe brain damage). Perhaps part of the problem lies in "Figure 1," which shows the respective accelerations for shaking and impact. The authors used widely different scales which gives the two graphs a misleadingly similar shape.
87. Mark N. Hadley et al., *The Infant Whiplash-Shake Injury Syndrome: A Clinical and Pathological Study*, 24 *Neurosurgery* 536 (1989).
88. *Id.* at 536.
89. *Id.*
90. *Id.* at 537.
91. *Id.* at 539.
92. Eva Lai Wah Fung et al., *Unexplained Subdural Hematoma in Young Children: Is it Always Child Abuse?*, 44 *Pediatrics Int'l* 37, 40 (2002) ("It is therefore not clear to what extent these conclusions are a self-fulfilling prophecy, that is, defining child abuse [simply] on the basis of [the existence of the two markers.]").
93. Ann-Christine Duhaime et al., *Head Injury in Very Young Children: Mechanisms, Injury Types, and Ophthalmologic Findings in 100 Hospitalized Patients Younger Than 2 Years of Age*, 90 *Pediatrics* 179 (1992) [hereinafter Duhaime, 1992].
94. *Id.* at 180 fig.1.
95. *Id.* at 184.
96. *Id.*
97. *Id.* at 183.
98. *Id.* at 184.
99. If a child has retinal hemorrhaging it is considered presumptive proof that it was caused by non-accidental means. So, the population of head injuries considered non-accidental is filled with babies with retinal hemorrhages. The population is then examined and surprise is announced when large numbers of infants with retinal hemorrhages are found.
100. Ann-Christine Duhaime et al., *Nonaccidental Head Injury in Infants - The "Shaken-Baby Syndrome"*, 338 *New Eng. J. Med.* 1822 (1998) [hereinafter Duhaime, 1998].
101. *Id.* at 1826-27.
102. *Id.* at 1827.
103. *Id.*
104. *See American Academy of Pediatrics*, *supra* note 5, at 206 ("The act of shaking leading to shaken baby syndrome is so violent that individuals observing it would recognize it as dangerous and likely to kill the child. Shaken baby syndrome injuries are the result of violent trauma."); Barton D. Schmitt, *The Child with Nonaccidental Trauma*, in *The Battered Child* 178, 188 (Ray E. Helfer & Ruth S. Kempe eds., 4th ed. 1987) ("Inflicted

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subdural hematomas can also occur without skull fractures, scalp bruises, or scalp swelling... These findings used to be erroneously called "spontaneous subdural hematomas," but evidence clearly points to a violent, whiplash shaking mechanism."); Kivlin, *supra* note 21, at 158 ("Retinal hemorrhages are the most common fundus finding in the shaken baby syndrome."). After the trial of Louise Woodward for the shaking death of Matthew Eappen, fifty-four medical experts stated that "well established medical evidence ... overwhelmingly supported [that] a violent shaking/impact episode" killed the baby and that, furthermore, SBS comprises "swelling of the brain ... , bleeding within the head ... , and bleeding in the interior lining of the eyes." Shaken baby syndrome - A Forensic Pediatric Response, Nov. 16, 1997, at <http://www.olywa.net/cagle/webchild/matt.html> (last visited Oct. 10, 2003).

105. Ind. Code 16-41-40-2 (2002).
106. See, e.g., *Johnson v. Sec'y of Health & Human Services*, 1997 WL 368375, at 5 (Fed. Cl. Apr. 29, 1997) (holding child's serious injuries caused by abuse, not vaccination. "To summarize, this evidence indicates that when an infant has the particular combination of injuries that Devin had (i.e., subdural hematoma, brain swelling, and retinal hemorrhaging) such injuries are very likely to have been caused by physical trauma" (citation omitted)); *United States v. Wright*, 1998 WL 142432, at 3 (A.F. Ct. Crim. App. Mar. 13, 1998) (holding caretaker guilty of negligent homicide when baby in her care died, where autopsy revealed subdural hematoma, retinal hemorrhaging, and cerebral swelling); *State v. Gunn*, 57 S.W.3d 347, 349 (Mo. Ct. App. 2001) (setting forth doctor's testimony that "retinal hemorrhage and subdural hematoma are classic injuries associated with a baby who has been violently shaken. Dr. Blair [also] testified that he was one hundred percent certain that the retinal hemorrhages were caused by shaking."); *State v. Mascarenas*, 4 P.3d 1221, 1222 (N.M. 2000) ("The treating physician diagnosed Matthew's injuries as subdural hematoma, cerebral edema, and cardio-pulmonary arrest all of which were consistent with shaken baby syndrome."); *State v. Talbot*, 972 P.2d 435, 436 (Utah 1998) (holding that child said to have fallen off bunk-bed reported by medical examiner to have suffered from SBS and she "died as a result of abnormal, massive craniocerebral injuries inflicted upon her by an outside force").
107. R. Uscinski, Shaken Baby Syndrome: Fundamental Questions, 16 Brit. J. Neuro-surgery 217 (2002).
108. *Id.* at 217.
109. See *id.*
110. Angular acceleration of about 4000 radians/s[su²]. *Id.*
111. The injuries included concussion, subdural hematoma, and injuries to functional tissues. *Id.*
112. *Id.* at 218.
113. *Id.*
114. *Id.*
115. Fung et al., *supra* note 92, at 41 (discussing different markers for child abuse in Japan, Hong Kong, and United States).
116. Susan R. Durham et al., Age-Related Differences in Acute Physiologic Response to Focal Traumatic Brain Injury in Piglets, 33 Pediatric Neurosurgery 76, 76-82 (2000).

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117. J.F. Geddes et al., *Neuropathology of Inflicted Head Injury in Children II: Microscopic brain injury in infants*, 124 *Brain* 1299, 1299 (2001) [hereinafter, Geddes, *Microscopic brain injury*]. As mentioned before, there is a problem with the concept of "inflicted" injury here, in that it includes twenty-one cases where there was no "significant extracranial injury" or "other significant neuropathology." *Id.* at 1302 tbl.2. To wit, the injuries were most likely deemed to be inflicted because of the nature of the injury itself, rather than by some external reason.
118. *Id.* at 1303-05.
119. *Id.* at 1305. Diffuse axonal injury is the indication of severe damage to the brain caused by traumatic deceleration injuries such as those described by Caffey, *supra* text accompanying note 4.
120. "Apnea may well be, ... an integral part of many severe cases of non-accidental infant head injury or shaken-baby syndrome. The hypoxic damage resulting from apnea would lead to severe brain swelling, which is the usual cause of death." Geddes, *Microscopic brain injury*, *supra* note 117, at 1304.
121. See, e.g., *Powell v. State*, 522 S.E.2d 656, 656 (Ga. 1999) (convicting father of felony murder after he confessed to shaking daughter in attempt to revive her after she stopped breathing); *Andrews v. State*, 811 A.2d 282, 286 (Md. 2002) (convicting father of reckless endangerment when he admitted to lightly shaking baby daughter after she stopped breathing); *State v. Maze*, 2002 WL 1885118, at 2 (Tenn. Crim. App. Aug. 16, 2002) (sentencing father to twenty-one years after he admitted shaking five-week-old baby in attempt to resuscitate him after child stopped breathing).
122. Geddes, *Microscopic brain injury*, *supra* note 117, at 1304.
123. David I. Graham, Editorial: Paediatric head injury, 124 *Brain* 1261, 1262 (2001) ("The most important finding was that the predominant neurohistological abnormality in the cases of non-accidental injury in infants was due to hypoxia and not diffuse axonal injury. Although not commented upon it is not clear if, when interpreting this type of case material, there may be a need to consider the vascular complications of hypoxia and/or raised intracranial pressure.").
124. Geddes, *Microscopic brain injury*, *supra* note 117, at 1300.
125. *Id.*
126. *Id.*
127. Geddes, *Patterns of brain damage*, *supra* note 17.
128. *Id.* at 1298.
129. *Id.*
130. *Id.*
131. *Id.*
132. Cyril H. Wecht, Letter to the Editor, 20 *Am. J. Forensic Med. & Pathology* 301, 301 (1999) (stating that diagnosis of SBS "is made much too frequently and is definitely much too zealously ... pursued").
133. Brian J. Clark, Letter to the Editor, 125 *Brain* 677, 677-78 (2002) ("urging caution in assuming that all children with retinal haemorrhages have been violently shaken").
134. Caffey, *supra* note 4, at 400-01 (suggesting that even though "many features of post-traumatic subdural hematomas are not satisfactorily explained or understood," the cause is probably "repeated whiplash shaking").

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135. Shervin R. Dashti et al., Current Patterns of Inflicted Head Injury in Children, 31 *Pediatric Neurosurgery* 302, 302-03 (1999) (examining "patterns of head trauma associated with child abuse").
136. Hadley, *supra* note 87, at 539.
137. American Association of Pediatrics, *supra* note 5, at 206.
138. Matthieu Vinchon et al., Infantile Subdural Hematomas due to Traffic Accidents, 37 *Pediatric Neurosurgery* 245, 251-52 (2002).
139. Popper provides a wonderful example of circularity: "Why is the sea so rough today? - 'Because Neptune is very angry' - 'By what evidence can you support your statement that Neptune is very angry?' - 'Oh, don't you see how very rough the sea is? And is it not always rough when Neptune is angry?' This explanation is found unsatisfactory because ... the only evidence for the [state of affairs to be explained] is the [explanation] itself." Karl Popper, *The Aim of Science* (1957), in *A Pocket Popper* 163 (David Miller ed., 1983).
140. Geddes, Patterns of brain damage, *supra* note 17, at 1297. See also John Plunkett, Fatal Pediatric Head Injuries Caused by Short-Distance Falls, 22 *Am. J. Forensic Med. & Pathology* 1, 9 (2001) ("Any sudden increase in intracranial pressure may cause retinal hemorrhage. Deformation of the skull coincident to an impact non-selectively increases intracranial pressure.").
141. Two examples can be found *supra* text accompanying notes 78 and 82.
142. See Duhaime, 1987, *supra* text accompanying notes 79-86.
143. Geddes, Microscopic brain injury, *supra* note 117, at 1299.
144. *Id.* at 1304-05.
145. *Daubert*, 509 U.S. at 593.
146. Brian J. Clark, Letter to the Editor, 22 *Am. J. Forensic Med. & Pathology* 415, 415 (2001) (arguing that hypothesis of SBS is not established fact and should not be thought of as such).
147. 439 S.E.2d 645 (1994).
148. *Id.* at 647.
149. *Id.* at 649.
150. *Id.* at 647.
151. 4 P.3d 1221 (N.M. 2001).
152. *Id.* at 1223 ("The treating physician diagnosed Matthew's injuries as subdural hematoma, cerebral edema, and cardio-pulmonary arrest all of which were consistent with shaken baby syndrome.").
153. *Id.* ("One State expert witness did concede that there was a debate within the medical community as to whether one shake was sufficient to cause the injuries associated with SBS.").
154. *Id.* at 1221.
155. For an example of a court case with such an assertion, see *Jones*, 439 S.E.2d at 647 (stating that to cause symptoms of SBS seen in child "the fall would have to be from a third or fourth floor of a building"). For an example from the medical field, see Dashti, *supra* note 135, at 303 ("For young children, it is widely accepted that minor falls and often even major falls of 10 feet or more do not produce severe intracranial damage, although skull fractures are common.").
156. Plunkett, *supra* note 140, at 10.

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157. *Id.* at 3 tbl.1.
158. *Id.*
159. *Id.*
160. See Mark S. Dias et al., Serial Radiography in the Infant Shaken Impact Syndrome, 29 *Pediatric Neurosurgery* 77 (1998) (finding that symptoms previously interpreted as chronic subdural hematoma can appear after just one injury); Vinchon, *supra* note 138, at 245 (examining eighteen cases of subdural hematoma in infants caused by traffic accidents and finding that "hallmark of repeated trauma," mixed-density collections on CT scans, can be created by single recent trauma).
161. See Duhaime, 1987, *supra* text accompanying note 79.
162. *Daubert*, 509 U.S. at 584.
163. *Brief for Respondent at 5, 11, Daubert*, 509 U.S. 579 (1993) (No. 92-102) (arguing that plaintiffs' evidence has been found insufficient to prove causation because "of the roughly 2000 Bendectin cases that have been filed - the vast majority of which have already reached final judgment - only one case has resulted in an affirmed jury verdict for the plaintiff" and arguing that "overwhelming body of data [] contradict [the petitioner's] conclusion").
164. *Reply Brief of Petitioners at 3, Daubert*, 509 U.S. 579 (1993) (No. 92-102) ("The methods employed by petitioners' experts are precisely the methods routinely employed by scientists, indeed, prescribed by federal regulations, to assess the probability that a particular drug is causing observed injuries."). For a fuller discussion of the scientific issues underlying the *Daubert* decision, see Kenneth J. Chesebro, Taking *Daubert's* "Focus" Seriously, 15 *Cardozo L. Rev.* 1745, 1749-50 (1994).
165. On remand, the Ninth Circuit held that the plaintiff's evidence was not admissible under the *Daubert* standard, stating that "the strongest inference to be drawn for plaintiffs based on the epidemiological evidence is that Bendectin could possibly have caused plaintiffs injuries." *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 43 F.3d 1311, 1322 (9th Cir. 1995).
166. *Kempe*, *supra* note 71, at 3288-89.

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Dural haemorrhage in non-traumatic infant deaths: does it explain the bleeding in 'shaken baby syndrome'?

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Dural haemorrhage in non-traumatic infant deaths: does it explain the bleeding in 'shaken baby syndrome'?

A histological review of dura mater taken from a *post-mortem* series of 50 paediatric cases aged up to 5 months revealed fresh bleeding in the dura in 36/50, the bleeding ranging from small perivascular haemorrhages to extensive haemorrhage which had ruptured onto the surface of the dura. Severe hypoxia had been documented clinically in 27 of the 36 cases (75%). In a similar review of three infants presenting with classical 'shaken baby syndrome', intradural haemorrhage was also found, in addition to subdural bleeding, and we believe that our findings may have relevance to the pathogenesis of some infantile subdural haemorrhage. Recent work has shown that, in a proportion of infants with fatal head injury, there is little traumatic brain damage and that the significant finding is

craniocervical injury, which causes respiratory abnormalities, severe global hypoxia and brain swelling, with raised intracranial pressure. We propose that, in such infants, a combination of severe hypoxia, brain swelling and raised central venous pressure causes blood to leak from intracranial veins into the subdural space, and that the cause of the subdural bleeding in some cases of infant head injury is therefore not traumatic rupture of bridging veins, but a phenomenon of immaturity. Hypoxia with brain swelling would also account for retinal haemorrhages, and so provide a unified hypothesis for the clinical and neuropathological findings in cases of infant head injury, without impact or considerable force being necessary.

Keywords: infant head injury, non-accidental injury, subdural haemorrhage

Introduction

For many authors, subdural haemorrhage (SDH) in infancy has become synonymous with inflicted trauma, particularly when associated with retinal haemorrhages, despite the fact that accidental injury in this age group has also been documented to result in subdural and retinal bleeding [20,28,33]. The existence of isolated reports of

supratentorial SDH occurring *in utero* [2,17,21], or in neonates and infants from causes apart than trauma [8,26,30,31], is an indication that as in other areas of medicine, several mechanisms may lead to the same clinical picture [6]. Nevertheless, the term 'shaken baby syndrome' tends to be automatically applied to any infant with a swollen brain, subdural and retinal bleeding. This label, alleging as it does non-accidental injury, effectively precludes any further discussion of how these clinical features might have been caused, even though all of them, both singly and in combination, may be seen in conditions

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other than trauma. We have reviewed sections of dura taken from a *post-mortem* series of 50 cases who had died under 1 year of age, none of whom had sustained a head injury, and compared them with the findings in three cases of classical 'shaken baby syndrome'. Our findings lead us to propose an alternative, non-traumatic, aetiology for subdural and retinal bleeding in these infants.

Subjects and methods

A review of samples of dura from paediatric autopsies was approved by the Tissue Subcommittee of the East London and City Health Authority Research Ethics Committee. These were a consecutive series of infant cases in which informed parental consent had been obtained for tissue to be taken at *post-mortem*; a formal review was initiated to investigate the significance of haemorrhage associated with the dura.

The series comprised 50 cases with age at birth of 18–41 weeks. There were 17 intrauterine deaths (IUD), three spontaneous abortions, 16 perinatal deaths (less than 7 days after birth), five neonatal deaths (occurring within the first postnatal month) and nine deaths in infancy (children under one year of age). Median survival of the 30 perinatal, neonatal and infant cases was 1 week. The two oldest children were aged 5 months, although one had been born prematurely at 23 weeks and survived 10 months (corrected developmental age 5 months). Cases in which there had been a therapeutic termination of pregnancy were excluded. None of the cases had suffered a head injury. A full *post-mortem* (with the exception of the eyes, which were not examined) had been performed by a paediatric pathologist, and the clinical course of all those children who had survived after delivery was available. Clinical details were used in addition to the *post-mortem* report to establish the mode of death in any case where the child had lived; otherwise, this was determined from the underlying condition, where known, and from the macroscopic and microscopic changes found at *post-mortem*.

The brain weight had been recorded in every case. The pathologist had noted on removal of the brain that the dura in many cases was 'haemorrhagic' or 'congested', but in only one case had there been macroscopic evidence of subdural bleeding: a female born at 25 weeks who developed fulminating *Enterobacter* septicaemia secondary to severe chorioamnionitis, and died 1 week later, having been in intensive care since birth. A large unilateral sub-

dural haematoma was found at *post-mortem*, acting as a mass lesion.

Between one and three strips of dura from each case had been processed and embedded on edge, and a Perls stain and immunohistochemistry for CD68 (PG-M1) performed. The slides were reviewed by a single pathologist, who was blind to the clinical details.

Infants with head injury

An additional series of dural samples was reviewed from three infants from an acute head injury, believed to have been inflicted. The children were aged 8 months, 7 weeks and 5 weeks at the time of injury, and the immediate cause of death in all had been raised intracranial pressure (ICP). They all had documented retinal haemorrhage. Bilateral subdural bleeding had been seen on *pre-mortem* scans and was confirmed at *post-mortem*. None had either a skull fracture or subscalp bruising, and all had marked brain swelling, manifest as significantly increased brain weight, with severe hypoxic brain damage on histology. One of the three had extracranial injury in the form of old rib fractures. The three had previously been included in a large series of non-accidental head injury [12,13], and were the only infant cases from that series in which sections of dura were still available.

Results

Findings in 50 cases without head injury

The immediate causes of death were infection ($n=6$), hypoxia ($n=26$), infection with documented severe hypoxia ($n=8$) and Sudden Infant Death Syndrome (SIDS) (4). Six deaths, five of them intrauterine, remained unexplained after *post-mortem*.

The only significant pathology, present in 36/50 cases, was bleeding inside the strips of dura (intradural haemorrhage, IDH) as illustrated in Figure 1. All the intradural bleeding was fresh: there was no haemosiderin, Perls' positivity or evidence of a macrophage reaction in any of the 36 cases, suggesting that the bleeding found at *post-mortem* was likely to have occurred less than 2–3 days before death [3]. In at least 24/36 (66%), delivery could be excluded as an aetiological factor in the bleeding, because IDH was present in 11 of the 17 cases that had died *in utero* and in 13 of the 18 infants who lived for 5 days or more (median 23 days). Fifteen children had not died *in utero*

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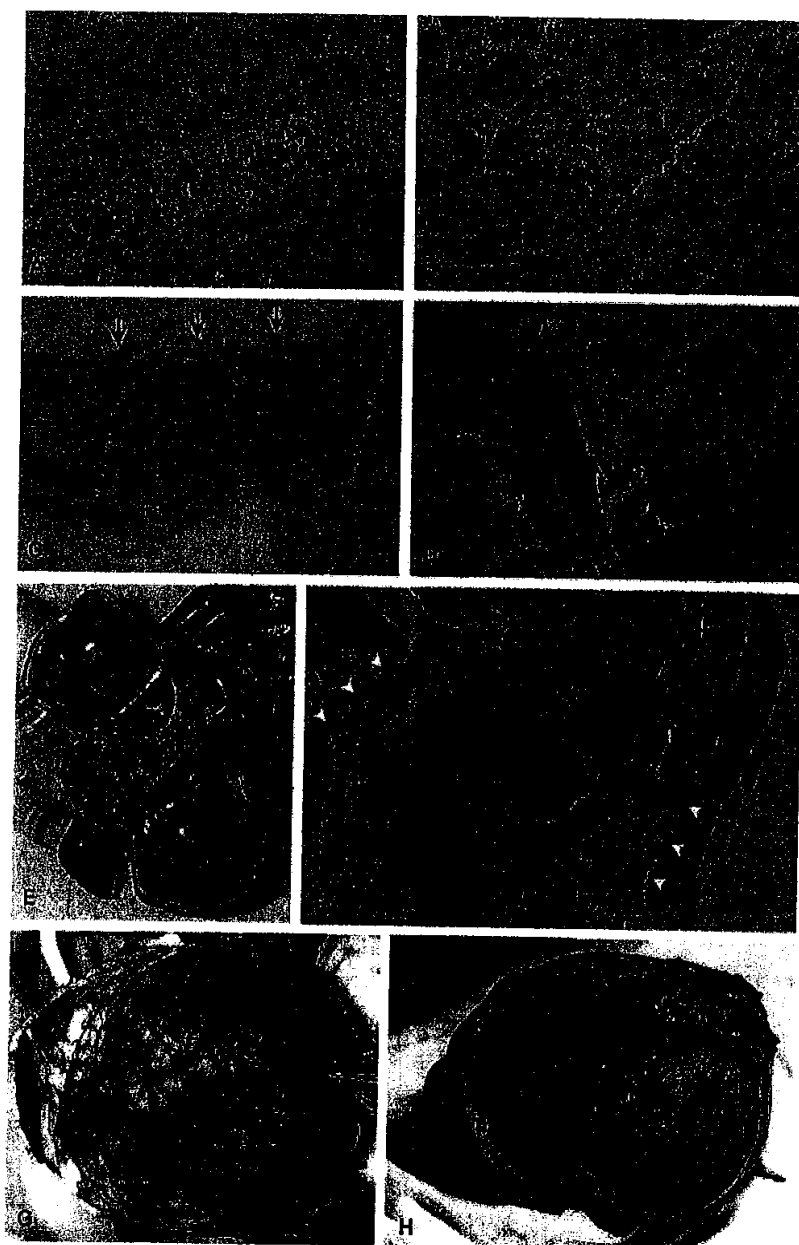


Figure 1. (a–d) Intradural and juxtadural bleeding in four non-traumatic infant autopsies. (a) Showing minimal extravasation of red blood cells; (b) More extensive bleeding confined to the dura. In (c) and (d), arrows indicate where blood has ruptured through the dura and lies on the surface (all haematoxylin and eosin). (e) Florid intradural bleeding with some subdural blood adherent to the dura of a 26-week-old-fetus, who died *in utero* after placental abruption. (f) Dura from a case of non-accidental head injury, stained with haematoxylin van Gieson; the two edges of the dura are indicated by white arrowheads. Blood (yellow) has dissected between layers of collagen (red), and ruptured through on to the subdural surface, on the right. (g,h) Two cases of non-accidental infant head injury at *post-mortem*, showing the typical appearance of the subdural bleeding in such cases. The bleeding lies over both hemispheres. In (h), there is a small collection in the interhemispheric fissure. Note that virtually all the surface blood is subdural; a small amount of subarachnoid haemorrhage is present in the sulci.

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but survived less than 5 days. Eight of these had a spontaneous vaginal delivery, of whom five had IDH. Of the five delivered by Caesarean section, four had IDH, three of them severe (++). Two others, both with severe IDH, had a ventouse extraction and a failed ventouse plus Caesarean section, respectively.

The extent of the haemorrhage in the samples was graded as '0' (meaning none, or only minimal extravasation of small groups of red cells), '+' (small haemorrhages round several vessels) and '++' (florid IDH; widespread foci of haemorrhage, sometimes occupying the full thickness of the dura). Table 1 summarizes the data according to degree of IDH and type of death. In 11 of 50 cases, blood had ruptured right through the collagen, on to its outer surface (Figure 1c,d, Table 2). We have used the term 'juxtadural bleeding' to describe these cases, where we were

unable to tell from sections whether the blood was lying in the extradural or subdural space.

The cause of the large unilateral SDH in the 25-week-old-fetus described above was not found, but assumed to have resulted from severe sepsis and disseminated intravascular coagulation [26].

Brain weights were compared to standard paediatric tables. Where they fell outside the normal range for the age, values were compared with the actual size and weight of the body. The weight of the brain was found to be normal in 32 cases, reduced in five and raised in one. In 12 further cases, the clinical history and/or the degree of maceration suggested that the child had been dead *in utero* for more than 24 h, so the brain weight was disregarded for the purposes of this review because it possibly did not reliably reflect the state of the brain at the time of death. The one case in which the brain weight was increased to a level that might have caused raised ICP was a 1-month-old infant whose cause of death remained unascertained after *post-mortem*. Intradural bleeding was present in that case.

There was an association between the occurrence of severe IDH (graded '++') and the type of case: florid bleeding was seen in 55% (11/20) intrauterine deaths and spontaneous abortions; 69% (11/16) perinatal deaths and only 14% (2/14) neonatal and infant deaths ($P < 0.001$) (Table 2). The results for IUD and spontaneous abortion were similar, and so these two groups were combined as cases that had no postnatal survival; for the same reasons, the results for neonatal and infant deaths were also combined. Table 3 documents the association between IDH, infection and hypoxia in 40 cases for which the cause of death was known: there was no evidence of a relationship between IDH and infection ($P = 0.72$) and only a slight indication of one with hypoxia ($P = 0.15$); the percentage of cases that were hypoxic and had an IDH was 79% compared to only 50% in the cases that were not hypoxic. Although this could be considered to be an important difference, chance cannot be ruled out. However, because the P value was not far from 0.05, the lack of statistical significance is probably due to the small number of cases, in particular those without hypoxia, of which there were only six in total.

Table 1. The number of cases according to type of death and degree of IDH

Type of death	IDH grading*			All
	0	+	++	
Spontaneous abortion	2	1	0	3
Intrauterine death	5	0	10	15
Stillbirth	0	1	1	2
Perinatal death	2	3	11	16
Neonatal death	2	3	1	6
Infant death	3	4	1	8
All	14	12	24	50

0, No haemorrhage, or only minimal extravasation of small groups of red cells; +, small haemorrhages round several vessels; ++, florid IDH; widespread foci of haemorrhage, sometimes occupying the full thickness of the dura.

Table 2. Relationship between severe intradural bleeding (graded '++') and type of case

Type of case:	Severe IDH present?	
	Yes (++)*	No (0, +)*
IUD, spontaneous abortion	11 (55%), 7 had JDH	9
Perinatal death	11 (69%), 3 had JDH	5
Neonatal and infant death	2 (14%), 1 had JDH	12
Total	24 (48%)	26

JDH, Juxtadural haemorrhage; bleeding that had ruptured the outer layer of the collagen, with clot lying on the outer surface of the dura (Figure 1c,d). *0, no haemorrhage, or only minimal extravasation of small groups of red cells; +, small haemorrhages round several vessels; ++, florid IDH; widespread foci of haemorrhage, sometimes occupying the full thickness of the dura.

Cases of infant head injury

The samples of dura from three cases of presumed head injury all showed recent IDH, which had not been noted in the original histological report, as well as SDH. In these

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Table 3. Relationship between the presence of intradural bleeding, infection and hypoxia in 40 cases (after exclusion of six unexplained deaths and four SIDS)

Cause of death:	IDH present?	
	Yes (+, ++)*	No (0)*
Infection?		
Yes	10 (71%)	4
No	20 (77%)	6
Hypoxia?		
Yes	27 (79%)	7
No	3 (50%)	3
Mixture		
Infection only	3 (50%)	3
Hypoxia only	20 (77%)	6
Infection & hypoxia	7 (88%)	1

0, No haemorrhage, or only minimal extravasation of small groups of red cells; +, small haemorrhages round several vessels; ++, florid IDH; widespread foci of haemorrhage, sometimes occupying the full thickness of the dura.

cases, the two surfaces of the dura were identifiable and, in two of the three, the blood appeared to have dissected from the dura into the subdural space (Figure 1f).

Discussion

The principal finding in this series of 50 non-traumatic paediatric autopsies, from deaths *in utero* up to infants aged 5 months, is that varying degrees of intradural and juxtadural bleeding were present in 72% of cases (36/50). In two-thirds of these, delivery-related trauma could definitely be excluded as a cause. This finding is particularly important because we have observed identical bleeding in three infants presenting as classical 'shaken baby syndrome'.

IDH (meaning haemorrhage within the dura as opposed to the more usual meaning in clinical practice of haemorrhage beneath the dura) is often seen in biopsies from adults or older children as an artefact of surgery, but not in dura taken at *post-mortem* from these age groups. However, it was very common in the paediatric autopsies we reviewed, and Figure 1 demonstrates that, in such cases, much of the dura of the calvaria may contain haemorrhage (e). Our study may well have underestimated the incidence of bleeding in this cohort, since, in most cases, only one sample of dura was taken.

The series we have studied reflects the practice of a teaching hospital paediatric pathologist, and most of the subjects had been profoundly hypoxic before death, as a

result of conditions such as bronchopneumonia, congenital heart or lung disease, placental insufficiency (both acute and chronic), septicaemia and birth asphyxia. Petechial haemorrhages in many internal organs, including in the dura, are well recognized by paediatric pathologists to be a characteristic finding in cases of birth asphyxia [11,35], while an early study documented intradural bleeding as a 'constant finding' in premature infants [5]. Similarly, venous hypertension and asphyxial cardiovascular damage have been implicated in the aetiology of acute convexity subdural and primary subarachnoid haemorrhage in newborn infants, and in intracerebral bleeding [11,15,34]. Mechanical compression of the head and rises in central venous pressure during delivery may contribute to neonatal intracranial haemorrhage, but they were not the cause of the IDH in at least 66% of our 36 cases, in whom the primary mechanism was likely to have been hypoxia-induced alterations in the permeability of immature vessels, causing blood to leak into the extravascular compartment. The collagen layers of the infant dura are generally much more cellular and less compact than in older subjects, and so do not tend to impede the extravasation of blood [5].

Intracranial pathology in non-accidental injury

A recent study by Geddes *et al.* [14] described the neuropathology of 53 cases of inflicted head injury in detail. Perhaps the most unexpected finding was that few of the 37 infants in that series showed anything in the way of traumatic brain damage, apart from craniocervical damage in approximately one-third of the cases, the microscopy being compatible with stretch injury to the neuraxis. The authors proposed that in those cases hyperflexion-hyperextension of the neck had caused primary brainstem damage, which in turn had provoked apnoea, resulting in global hypoxia and catastrophic secondary brain swelling. Hypoxia, known from neuroradiological studies to be a cardinal feature of infant head injury, was an important finding in that series: 78% of infants presented with apnoea or respiratory difficulties, while 84% had microscopic evidence of global hypoxia. In fact, in a significant proportion, hypoxic damage was the only pathology found in the brain. Secondary hypoxic brain swelling was the most frequent cause of death, with subdural and retinal bleeding present in 84% and 70% of infants, respectively [12,13].

These findings suggested a mechanism which would explain most of the clinical picture of 'shaken baby syn-

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drome', but which left the SDH unexplained. Because stretch injury to the craniocervical junction need not involve either violence or impact, it has been calculated that the maximal forces involved in shaking a baby, derived from experimental work [7,23], do not reach the threshold necessary to rupture cortical bridging veins, if there is no impact to the head. A number of fatal cases show no evidence of impact, even after careful examination, a fact that is usually explained away by suggesting that the head must have been decelerated (or 'slammed') against a soft surface, such as a mattress. However, what is usually ignored is that the typical subdural haemorrhage in infants is quite different from that seen in older children or adults. Characteristically spread over both hemispheres, often no more than a thin film, but sometimes with small collections of blood in the interhemispheric fissure, it does not require neurosurgical intervention; SDHs acting as mass lesions tend to be seen in older age groups [12,13]. The question arises: if the assumed circumstances of the incident (severe shaking, with or without impact, the force equivalent to a fall from a two storey window or involvement in a high speed road traffic accident) do not fit the observed neuropathology in many of the infants, could there be another source (and, possibly, mechanism) of bleeding for this unique form of SDH?

Relevance of intradural bleeding: a hypothesis

The three cases of inflicted head injury reviewed here also had intradural bleeding, and in two of the three blood was present through all the layers of collagen, in continuity with the blood in the subdural space. We suggest that hypoxia-related leakage of blood from veins both inside the dura and in the subdural space was the source of the subdural haemorrhage found in each case, rather than traumatic rupture of bridging veins.

What would be the mechanism of IDH in non-accidental injury? Most infants with inflicted head injury have severe hypoxic brain damage and rapidly develop grossly raised ICP from secondary brain swelling, which is documented on a scan taken on arrival at hospital, and confirmed at *post-mortem* by markedly increased brain weight [12,13]. Our observations in the present series indicate that, in the immature brain, hypoxia both alone and in combination with infection is sufficient to activate the pathophysiological cascade which culminates in altered vascular permeability and extravasation of blood within and under the dura. In the presence of brain swelling and raised intracra-

nial pressure, vascular fragility and bleeding would be exacerbated by additional haemodynamic forces, such as venous hypertension, and the effects of both sustained systemic arterial hypertension and episodic surges in blood pressure.

The interactions between factors such as venous pressure, blood pressure and brain swelling are potentially complex. Cerebral venous hypertension occurs when there is an obstruction to flow, which is the situation where there is cerebral swelling. The dural venous drainage, in the main, is via the meningeal veins which originate in plexiform venous channels within the dura, and drain eventually into the superior sagittal and other intracranial sinuses; only the posterosuperior group of vessels drain externally, via the jugular foramen [36]. We hypothesize that the presence of severe brain swelling with venous congestion would produce widespread 'oozing' from leaky hypoxic dural veins, possibly with a contribution from similarly leaky bridging veins, and that this is responsible for the typical thin film or patchy collections of subdural blood. A significant additional contributor would be the systemic arterial hypertension, both sustained and episodic, that is commonly documented in children with raised intracranial pressure. This may occur as part of Cushing's triad (bradycardia, hypertension and raised intracranial pressure), or in blood pressure surges, characteristically seen for 1–2 h around the time of brainstem herniation or tentorial pressure 'coning'. Alternatively, blood pressure lability may be neurogenic in origin, resulting from lesions of the nucleus of the solitary tract [4,10], which could be particularly relevant in an infant with craniocervical injury. Whatever the cause, a rise in arterial blood pressure in a patient with cerebral oedema will increase external carotid flow to the arterial branches in the dura, which in turn would be transmitted to the already congested venous side, and so compound the effects of raised venous pressure. Finally, brain oedema is exacerbated both by superimposed hypercapnia resulting from respiratory abnormalities, and by arterial hypertension [18,24,25,27]. These three factors, cerebral venous hypertension and congestion, arterial hypertension and brain swelling, coupled with immaturity and hypoxia-related vascular fragility, provide an alternative physiological scenario for the characteristic subdural bleed of the 'shaken baby syndrome'.

Similarly, retinal haemorrhages can be explained by rises in intracranial and central venous pressure, with and without hypoxia [19,22]; they are also seen in a propor-

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tion of normal infants at birth [9], as well as in premature babies [1]. The incidence of retinal haemorrhage in neonates reported in the literature varies, possibly due to different patient demographics, difference in time after birth to examination and different examination techniques. In healthy newborns, it has been documented that delivery by Caesarean section reduces the risk of haemorrhage [9], although this is not always the case [29]; in premature infants, the mode of delivery does not appear to be associated with a different incidence of retinal haemorrhage [1]. In a prospective study of a consecutive series of premature infants, the occurrence of retinal bleeding was approximately one-half of that seen in term infants, and is believed to be partly explained by the effects of ventilation in reducing hypoxia, and thus abnormal vascular permeability and blood vessel fragility [1]. In the setting of inflicted infant head injury, it has never been proved that retinal bleeding is directly caused by shaking; rather, it is widely assumed that it results from the shearing forces of the injury, which simultaneously cause retinal and subdural bleeding and diffuse brain damage [16]. However, with the knowledge that most infant victims of non-accidental injury show very little if any traumatic pathology in the brain [13], it is appropriate to re-evaluate this assumption. We suggest that in many cases of non-accidental head injury retinal haemorrhages occur for essentially the same physiological reasons as subdural bleeding, as outlined above.

This constellation of events, severe hypoxic damage to immature blood vessels, exacerbated by raised ICP, central venous and systemic arterial hypertension, is not proposed to be the cause of all infantile subdural haemorrhages: for example, traumatic rupture of one or more

bridging veins would be a more likely explanation of significant unilateral bleeds. Nor is it necessarily the sole mechanism of retinal haemorrhages. However, if retinal and subdural bleeding are essentially secondary phenomena, and not directly the result of trauma (Figure 2), the sequence provides an explanation for all the findings in many cases of 'shaken baby syndrome', without impact or violence being necessary. Conversely, in cases in which there has obviously been significant impact (subscalp bruising and/or skull fracture with brain swelling), it would be unnecessary to postulate shaking as well, in order to account for retinal and subdural haemorrhages. Finally, a physiological rather than a traumatic mechanism for the bleeding would provoke further speculation: is it possible that occasional instances of 'shaken baby syndrome' may not be cases of 'shaking' or, indeed, of head injury at all? In a susceptible infant (for it is likely that, as in the adult, genetic factors play an important part in the individual response to a given cerebral insult [32]), subdural and retinal bleeding might result from any event that initiated apnoea or significant hypoxia, with brain swelling. Such a possibility highlights the difficulties posed by isolated cases in which there is nothing apart from subdural and retinal bleeding to substantiate an allegation of inflicted trauma; it is clear that extreme caution should be exercised by experts involved in such cases. In such circumstances, we suggest it would be better to use a descriptive term such as 'infantile encephalopathy with subdural and retinal bleeding', which has no aetiological implications rather than 'shaken baby syndrome'.

Finally, the frequency with which IDH has been found in our *post-mortem* series certainly makes it likely that intradural bleeding may also occur in children who do not die.

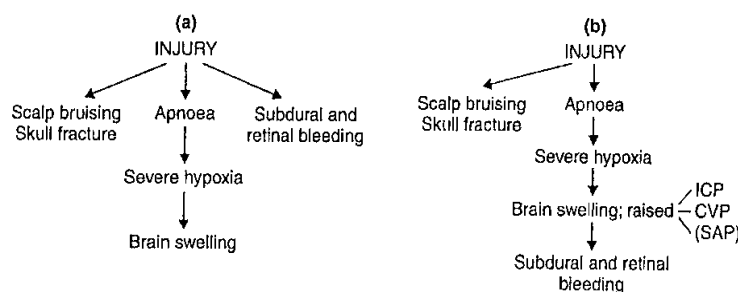


Figure 2. (a) Illustrates the traditional view of events in infant head injury, according to which retinal and subdural bleeding are a direct consequence of trauma. Our findings suggest that the sequence outlined in (b) may be more likely, with the bleeding being a secondary event. A full description is provided within the text. ICP, intracranial pressure; CVP, central venous pressure; SAP, systemic arterial pressure.

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For that reason, when examining sections of dura for medico-legal purposes, particularly in the context of 'timing' of injuries, histopathologists should not automatically ascribe the presence of any haemosiderin, macrophages (or even possibly organizing haemorrhage) to a previous head injury.

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SHAKEN BABY SYNDROME (SBS) AND NON-ACCIDENTAL INJURIES (NAI)

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This document is a de-identified extract from medical reports prepared in 1999 by Dr Mark Donohue in selected and typical cases of alleged shaking and injuries to infants. Its purpose is to provide a framework for assessing assumptions and evidence required for determining that particular injuries were caused by intentional and violent shaking. It is accompanied by a more general assessment of the "quality of evidence" in the research so far published (to late 1998) in the peer-reviewed medical literature, along with a listing of the references reviewed for both SBS/NAI and Terson's syndrome.

1 THE "SHAKEN BABY SYNDROME"

It is not possible to address the specifics of any particular case without addressing the general medical and scientific literature regarding the so-called "shaken baby syndrome" (SBS). I have performed such a review of the medical literature in order to assess the quality of evidence related to the diagnosis of SBS, and include this as Appendix I, along with the references reviewed.

The question which needs to be answered is not, "could this be a case of shaken baby syndrome?", because this is clearly one possibility. The questions which need to be answered would appear to be:

- 1/ "could this case represent anything other than SBS?"; and the related question
- 2/ "how certain are we that this was a case of SBS, as opposed to anything else?"

This report seeks to reach an objective answer to these questions in this particular case.

1.1 HISTORICAL ISSUES AND EVIDENCE FOR SBS

For doctors dealing with potentially abused children, the error of assuming abuse, even when none has occurred, is acceptable and (some would argue) necessary. It is certainly preferable to the alternative of failing to identify abuse which has occurred. In the past, the medical profession seems to have failed to identify cases of abuse, resulting in tragic outcomes for families and for the children not identified in particular.

In the last decade or so, a concerted effort has been made to address this historical blind-spot, and a number of advocacy groups for the rights of the child have emerged. Public educational campaigns have arisen, bringing the risks of shaking to the attention of the public, and the medical profession, particularly in hospital emergency settings, tends to scrutinise all cases of childhood injury or unexplained illness for evidence of abuse. On the whole, this has been a positive change, and may have resulted in decreases in death or injury of babies and children, although this has yet to be demonstrated.

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As with all "*swings of a pendulum*", however, there are associated dangers of such increased surveillance for abuse. The most obvious risk is that cases not associated with abuse will be incorrectly assumed to be abuse, and that the totality of evidence in cases will be ignored in favour of apparently "*incriminating*" evidence. I say this because it is, even in theory, impossible to attain perfection in the correct attribution of cause of injury. In the past, actual abuse cases were missed as a result. Now, cases unrelated to abuse are occasionally incorrectly attributed to abuse. The medical tests which are *supportive* of the diagnosis of non-accidental injury (NAI) have been pushed by many advocates as being *proof* of NAI generally, and SBS in particular.

The diagnosis of NAI and SBS rests on a number of factors, including medical and social history, family circumstances, medical examination, a wide range of test results, and the results of investigations and interviews by experienced multi-disciplinary teams. The diagnosis of NAI or SBS cannot ever rest upon the results of a few isolated investigations alone, as has been the case in recent years.

There are two main reasons for pursuing suspected NAI vigorously, namely:

- identifying and punishing any perpetrator, should the person be found; and
- decreasing further risk to the abused child and other children in the family.

While the medical profession may well be acting in the interests of the child by assuming NAI even when it has not occurred, one must recognise the potential for harm to the family and child where such assumptions prove to be incorrect. The decision on whether or not NAI has occurred, and who is responsible for it if it has occurred, must be made by the legal process, and such judgements must be dispassionate and based on evidence, rather than assertion by those wishing to protect the child. While it is self-evident that the safety and rights of the child must be protected in every case, the rights of the parents and carers cannot be ignored or forgotten in so doing.

There is a clear risk in assuming that abuse has occurred in cases where the evidence is weak, and where alternative opinions have not been adequately pursued and excluded.

The cases which I have so far reviewed would never have been investigated for potential abuse had it not been for the medical findings, as there was no evidence of or suggestion of abuse. In such cases, NAI has been assumed where other alternative explanations not only exist, but are arguably more likely than NAI.

Finally, the tendency of the medical profession to ignore the possibility of adverse reactions to vaccines, especially those containing thiomersal (a mercury preservative), is important.

In more than half of the cases I have reviewed, there is an apparent temporal relationship between the injury and prior vaccination with thiomersal-containing polyvalent vaccines or

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multiple simultaneous vaccinations. The vaccine typically leads to pyrexia and crying immediately following vaccination, and the infant is given paracetamol (acetaminophen) at increasing doses for control of crying and pyrexia in the following days. In most of these cases, a broad spectrum antibiotic has also been prescribed in the same period.

It has been suggested that the alternative explanation should be preferred, namely that the vaccination itself caused no injury, but induced crying which lasted for days, leading to frustration and eventual shaking by a parent or carer. Even if this is accepted, it raises a most interesting issue of ultimate causation. Had the vaccine(s) not been administered, the adverse reaction and crying would not have occurred, and there would have been no risk or likelihood of shaking or injury of any type. The acceptance of such crying and pyrexia as a "normal and expected" consequence of polyvalent vaccinations in up to 20% of infants does nothing to address the consequences of the crying and the increased risk of injury to the child from such a common event. It is disingenuous to argue that "*the disease would have been worse than the vaccination*", because the disease may or may not have occurred, and is a part of normal life of a child, whereas vaccination is a procedure requiring informed consent.

If one identifiable risk of vaccination is that of shaking and injury following prolonged crying (assuming that shaking *did* occur as a result of the vaccine-induced crying), then this needs to be conveyed to parents of children being vaccinated as part of the informed consent. If they are made aware of the potential for prolonged crying and pyrexia, and are told of the risks associated with shaking which may be a consequence of this crying, then the risk itself may be reduced.

Thus, it is arguable that vaccination is an *independent predictor* (or risk factor) for neurological injuries in infants, whether it is directly causative or predisposes to other outcomes which are causative. A recognition of the association (direct or indirect) may allow for action and warnings which may decrease the likelihood of adverse outcomes.

1.2 AXIOMS AND ASSUMPTIONS REGARDING ALLEGATION OF SBS

The case for this infant being the victim of intentional shaking rests upon certain axioms and assumptions, which may be reduced to the following:

- 1/ subdural haemorrhage (SDH) does not occur in a normal, healthy infant;
- 2/ SDH combined with retinal haemorrhage (RH) is pathognomonic of "*non-accidental injury*" (NAI);
- 3/ in the absence of identifiable external trauma, SDH and RH are only caused by violent "*acceleration/deceleration*" actions caused by an adult, otherwise known as "*shaken baby syndrome*";
- 4/ SBS must be intentional, or at least they would appear intentional and excessive to any dispassionate observer;
- 5/ the diagnosis of "*shaken baby syndrome*" can be made with absolute certainty on the basis of ophthalmological and radiological assessment alone.

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- 6/ the severity of shaking required to cause these findings would have been obvious, and was unrelated to any shaking or corporal punishment admitted to by family members.

I shall address each of these statements separately, and attempt to assess the evidence for and against each statement.

1.2.1 SPONTANEOUS SUBDURAL HAEMORRHAGE (SDH) DOES NOT OCCUR IN A NORMAL, HEALTHY INFANT

Clearly, SDH should not occur in a "normal healthy infant", although there is no medical or scientific evidence to back this assertion one way or the other. There is a logical difficulty, of course, in that any such cases which *did* occur in a "normal healthy infant" would almost certainly be attributed to NAI, whether or not there was other evidence to support such an attribution. This is a part of a broader defect of logic in NAI cases, that all unexplained injuries can be assumed to be NAI, which has been allowed to continue in an effort to protect the child.

There is evidence that SDH does occur in normal, healthy neonates as a result of birth trauma, and even in cases of normal, uncomplicated vaginal delivery.

There is clear evidence that SDH can be caused by anatomical, infectious and biochemical disorders which cause no obvious symptoms prior to the intracranial bleeding. In such circumstances, the infant appears "normal and healthy" (although probably not robustly healthy) despite the underlying, predisposing pathology.

Such disorders, predisposing to SDH, include:

- 1 arteriovenous malformations (AVM) or shunts (AVS);
- 2 certain infections such as malaria, hepatitis, septicaemia;
- 3 intravascular coagulopathy due to bacterial endotoxin;
- 4 certain malignancies, such as leukaemia;
- 5 clotting disorders;
- 6 accidental or intentional poisoning;
- 7 liver disease, such as microvesicular steatosis, hepatitis, etc;
- 8 gastrointestinal disorders, causing malabsorption, affecting trace elements, ascorbate or fat soluble nutrients (esp vitamins E and K);
- 9 metabolic disorders, such as Reye's syndrome, diabetes, disorders of energy metabolism;
- 10 inherited disorders, such as enzyme defects or chromosomal defects;
- 11 vascular and connective tissue disorders.

This list is not intended to be exhaustive. It is also possible that more than one predisposing factor existed, and that it was a combination of factors which led to the intracranial haemorrhage. For example, a mild factor XIII deficiency, when combined with

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malabsorption or Reye's syndrome, would be likely to result in a greater risk of intracranial bleeding than would any one of these factors alone.

In an infant under six months, such disorders may be asymptomatic, or may simply result in a non-specific failure to thrive. In some of these diseases, the first presentation is that of an intracranial bleed.

It is only possible to exclude these other causes by careful history taking, examination, appropriate and extensive testing, including assessment of nutritional status, enzyme levels, and assessing pathology of the liver, gut, kidneys, muscle, brain and heart.

It is my view, based on the cases I have reviewed, that there is a tendency to assume that NAI has occurred in infants with SDH and RH, and as a consequence of that assumption, there is a general failure in the first instance to pursue other potential causes or contributions to the injury as vigorously as would be expected.

Further, once the allegation of abuse has been made, and police or welfare services have become involved, there is a general unwillingness to consider any other plausible causes of the injury. In a sense, the parents or carer are assumed to be guilty, and have no logical way of "proving" their innocence. Investigations are continued, even if the infant dies, but those investigations are usually directed at building a stronger case for NAI (such as bone scan, MRI, autopsy), rather than identifying alternative causes or contributory factors.

1.2.2 SDH COMBINED WITH RETINAL HAEMORRHAGE (RH) IS PATHOGNOMONIC OF "NON-ACCIDENTAL INJURY" (NAI);

This is frequently the claim made by medical experts involved in the prosecution of SBS cases. Unless this relationship is proven, there is reasonable doubt that anyone shook or otherwise injured this infant.

The term "*pathognomonic*" implies a two-way relationship between the symptoms and signs on one hand, and the disease in question on the other hand. Pathognomonic symptoms or signs not only allow recognition of a disease, but differentiate it from all other diseases or disorders. Technically, it implies 100% specificity for the tests establishing the diagnosis.

The combination of SDH and RH strongly *support* a diagnosis of NAI, but in no way constitute *proof* that NAI occurred. The value of the diagnosis of SDH and RH is that their presence can markedly increase the confidence of a diagnosis of NAI, given *other* circumstances or findings which may indicate NAI.

Even if we assume that *all* non-accidental injuries involving shaking or blunt trauma to the head of babies cause subdural haemorrhage and retinal haemorrhage, it does not follow that all cases of SDH and RH are caused by NAI.

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One must know what other diseases or circumstances may cause SDH and RH. Since the mechanism of RH is unknown (Riffenburgh 1991), it is important that the *specific* hallmarks of NAI be delineated, as proposed recently (Rohrbach 1997).

Rohrbach (1997) has stated, "*Intraretinal haemorrhages alone are typical, though not pathognomonic for the 'battered-child syndrome'.*"

According to Rohrbach, the combination of the following provides increased certainty of NAI although there are clearly shortcomings in this single case study:

- 1 retinal haemorrhage;
- 2 crater-like appearance of central retina;
- 3 haemorrhagic retinoschisis; and
- 4 intraocular haemorrhages in the area of the circle of Zinn-Haller.

The ophthalmologists examining the infant needs to be questioned as to whether the changes seen in the particular case match these proposed criteria.

Conditions apart from NAI which may result in SD and RH include: bleeding disorders; meningitis; septicaemia; leukaemia; galactosaemia; hypertension; and Henoch-Schonlein purpura.

RH may also occur simply as a consequence of the intracranial bleeding. A number of papers which deal with the mechanism of the RH have suggested that the increasing intracranial pressure and subarachnoid haemorrhage lead to retinal haemorrhages (Jacobi 1986), and these may be accompanied by SDH.

In fact, this association is known as "*Terson's syndrome*". A number of papers (Giangiacomo 1985, Weingeist 1986, Jacobi 1986, Keithahn 1993, Poepel 1994) point out the similarities between Terson's syndrome and the retinopathy of shaken baby syndrome, with some suggesting that SBS should be considered in the differential diagnosis of Terson's syndrome.

Thus, there are other plausible and reasonable explanations for the combination of SDH and RH in an infant. Any of the factors listed above as potential causes of SDH must be considered a plausible cause of the RH as well.

The presence of SDH and RH is insufficient to prove any particular cause. It is likely that the majority of cases in which SDH and RH are found in infants under one year of age are NAI, but this is a statistical association. In any given case, these findings are only *supportive* of NAI. The case *must* stand or fall on other factors which would lead one to suspect NAI.

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1.2.3 IN THE ABSENCE OF EVIDENCE OF IDENTIFIABLE EXTERNAL TRAUMA, SDH AND RH ARE ONLY CAUSED BY VIOLENT "ACCELERATION/DECELERATION" ACTIONS CAUSED BY AN ADULT, KNOWN AS "SHAKEN BABY SYNDROME";

Most studies show a high proportion of NAIs are associated with other signs of trauma or abuse, either in the damaged infant or in other family members. In a recent British retrospective study (Jayawant 1998), about 60% showed signs of other trauma (bruising, fractures, resolving old SDH, etc). Other authors have suggested similar or higher percentages as showing signs of trauma or abuse, especially in cases of severe cerebral damage and death (Alexander 1990, Duhaime 1987, Lancon 1998).

As noted above, factors which may cause or contribute to SDH or SAH in an infant are likely to cause RH as well. A recent study (Jayawant 1998) noted an 80% association between SDH and RH, suggesting that RH is *not* an independent risk predictor, but a marker of severity and extensiveness of intracranial bleeding.

A number of authors (Duhaime 1987, Lancon 1998, Closset 1997) have suggested that shaking without impact does not generate sufficient forces to cause the types of injuries seen in SBS cases. Many others disagree, holding that choking forces tend to rupture the fragile veins across the dural space. These other authors propose ways in which shaking with a rotatory component, possibly at particular frequencies, or with rapid deceleration caused by soft impact (eg pillow, etc), could cause such shearing.

In fact, if this view of rotation at particular frequencies is correct, it is likely that the forces required to cause the damage observed may be less important than had previously been thought.

The essential ingredient of SBS would appear to be strong evidence of shaking and NAI. The majority of studies, however, assume that all unexplained cases of SDH and RH are SBS and NAI, and do not determine the degree of confidence that the assumption is correct.

In addition, the actions said to be required to cause NAI have changed over time from fore-aft shaking *with* impact, to severe and prolonged fore-aft shaking *without* impact, to rotatory acceleration-deceleration *without* impact, and more recently to rotatory acceleration-deceleration *with* soft object impact.

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Without a clear case definition, and without a means of proving whether an unobserved carer performed the particular actions required, the attribution of unexplained SDH and RH to SBS is neither provable nor disprovable. It is not a question which can be scientifically decided with current knowledge and techniques, and does not meet Popper's test of a valid scientific hypothesis (that an experiment can be defined which could disprove the hypothesis, were it to be incorrect). The diagnosis rests on the presence of sufficient "other factors" which would raise suspicion of NAI, and the clinical, ophthalmological and radiographic findings become supportive, rather than diagnostic, in such circumstances.

1.2.4 SBS MUST BE INTENTIONAL, OR AT LEAST THEY WOULD APPEAR INTENTIONAL TO ANY DISPASSIONATE OBSERVER;

This is, again, neither provable nor disprovable. Any concept of intention is not a medical or scientific issue, as it can only be decided by the person accused of shaking. As such, this becomes a matter for determination through the legal process. As the issue is one of degree (some degree of shaking and head movement in infants being an aspect of normal play and day to day life), the matter cannot be decided as it could for impact injuries, suffocation or penetrating injuries (which are not part of a continuum of normal life activities).

There are few data or cases in which the precise actions or forces used to create the injuries have been determined or observed. The lack of observational or experimental data make it impossible to determine what an independent, dispassionate observer would perceive.

It may be a reasonable assumption that the rareness of the SBS-type injury (estimated incidence in Britain at less than one in 4,000 children per year - Jayawant 1998) would imply excessive force. This may be a false assumption, however, if the damage arises from a particular type of action, rather than simply being a function of applied force. Rhythmic rotation of the baby at a particular frequency, for example, would be expected to lead to an amplification of applied force and relative motion between brain and skull in the infant. Such shaking may appear to be benign, yet cause significant damage to the dural vessels.

1.2.5 THAT THE DIAGNOSIS OF "SHAKEN BABY SYNDROME" CAN BE MADE CONFIDENTLY ON THE BASIS OF CLINICAL AND X-RAY ASSESSMENT ALONE.

As noted above, typical clinical and radiological changes seen in SBS cannot "make the diagnosis", but can strongly support the diagnosis made by other means. If the social and family circumstances are suggestive of NAI, then the medical investigations and clinical findings can increase the confidence that a NAI has occurred, and can help define the likely process of the NAI.

The question arises as to how one goes about excluding a diagnosis which has no formal definition, and no unique defining characteristics.

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A recent paper (Jayawant 1998) defines a number of characteristics of supposed and "proven" NAI in children in a retrospective study, and the findings of this would appear to suggest a set of criteria which, if applied, may increase the precision of the diagnosis.

Nine factors suggesting NAI are identified in children who have suffered SDH, namely:

Social and Family Issues

1. Sex of the child allegedly abused? *(two thirds are male)*
2. Sex of the alleged abuser? *(four fifths are male)*
3. Is there a past known history of abuse of this child or siblings by this alleged abuser? *(about one eighth have previously abused)*
4. Is the explanation/history internally consistent? *(over half of carers change their stories two or three times)*
5. Did the alleged perpetrator admit to shaking? *(about half do, eventually)*

Investigations and clinical findings

6. Haemoglobin at presentation less than 10 g/L *(seen in half of NAI cases)*
7. Skeletal survey *(positive in 60% of NAI cases tested)*
8. Evidence of some trauma or previous trauma *(seen in about 60% of NAI)*
9. Retinal haemorrhages *(present in 80% of cases)*

Of the nine proposed key factors in identification of NAI, the number found in any particular case may be important in determining likelihood of SBS/NAI.

1.2.6 THE SEVERITY OF SHAKING REQUIRED TO CAUSE THESE FINDINGS WOULD HAVE BEEN OBVIOUS, AND WAS UNRELATED TO ANY SHAKING OR CORPORAL PUNISHMENT ADMITTED TO BY FAMILY MEMBERS.

This can only be decided from an assessment of the social and family circumstances, and a knowledge of the family's past history and events around the time of the alleged injury.

Evidence would be required that one of those with access to the infant in the period during which the injury is thought to have occurred had previously shaken or abused either the baby or another member of the family. Additionally, the person would need to be proven to have the strength necessary to shake the child in the manner thought to be required to induce the injury.

Without such evidence, and based solely upon the presence of subdural haemorrhage and retinal haemorrhage, it would seem that the attribution of the pathology to intentional abuse cannot be sustained.

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APPENDIX I

RATING OF THE QUALITY OF EVIDENCE REGARDING SHAKEN BABY SYNDROME

In recent years, there has been a clear move towards basing medical practice and opinions on the best available medical and scientific evidence. This process has been termed "evidence based medicine" (EBM), and involves a review of the quality of evidence which is available in various diseases and fields of inquiry within medicine.

The aim of this appendix is to formally rank the available medical scientific evidence by internationally accepted methods, and to determine from this assessment the degree of confidence that can be held on certain views and approaches to SBS. This information should be available, and the shortcomings in research and knowledge on the subject should be made explicit.

This section aims to be neutral on the subject of shaken baby syndrome. This means that there is no selective quotation of the available literature, and literature is not chosen to support any particular view. The assessment is of the methods and quality of the actual research, and until this is complete, the content, findings and recommendations are irrelevant. At the end of the ranking, those studies which achieve the highest QER scores are reviewed for their content, findings and recommendations. Their outcomes are collated, and the entire published data set is then reviewed as a whole to determine the summarised recommendations, noting areas of agreement, conflict or controversy. From this, the problems with the published evidence are noted, and data gaps identified. Recommendations can then be made based on the summarised data.

In assessment of the quality of the available scientific evidence, I have taken an approach recently defined in Australia, and implemented in areas such as chronic fatigue syndrome (CFS) in the past two years, and in the setting of clinical practice guidelines. I draw on sections of such guidelines in this document, and I thank the original expert committee for their input.

Genuine hypothesis testing requires use of appropriate research methodologies including collection of relevant control data, and suitable statistical analysis. The interpretation of individual study findings may be constrained by factors such as whether the cohort examined was adequately representative of the patient population in general. Replication across studies and in independent research centres is a key factor in the reliability of evidence.

Compelling evidence comes from consistent findings in two or more well-constructed, controlled trials or population-based epidemiological studies (i.e., Level I or Level II evidence).

By contrast, clinical practice guidelines with Level IV evidence represent consensus statements of the expert panel, based upon clinical experience and limited scientific data. Although these statements may influence current practice, they are likely to be modified in response to further research findings.

Data from a single case series without control subjects provide little more than a stimulus for subsequent hypothesis testing. Such reports were not included in the systematic analysis of evidence upon which these guidelines are based.

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QUALITY OF EVIDENCE RATINGS

- I Consistent evidence obtained from more than two independent, randomised and controlled studies or from two independent, population-based epidemiological studies. Studies included here are characterised by sufficient statistical power, rigorous methodologies and inclusion of representative patient samples. Meta-analysis of smaller, well-characterised studies may support key findings.
- II Consistent evidence from two randomised controlled studies from independent centres, a single multicentre randomised controlled study or a population-based epidemiological study. Data included here have sufficient statistical power, rigorous methodologies and the inclusion of representative patient samples.
- III-1 Consistent evidence obtained from two or more well-designed and controlled studies performed by a single research group.
- III-2 Consistent evidence obtained from more than one study, but where such studies have methodological constraints, such as limited statistical power, or the inclusion of patient samples which may be non-representative.
- III-3 Evidence obtained from a single case study or a selected cohort study.
- III-4 Conflicting evidence obtained from two or more well-designed and controlled studies.
- IV Consensus opinions of authorities, based on clinical experience and /or descriptive reports.

SHAKEN BABY SYNDROME - Literature review (1966-98)

A. OVERVIEW AND METHODS

The entire Biomednet Medline database (<http://www.biomednet.com/db/medline>) was searched using the search term of "shaken baby syndrome" using Internet Explorer in late November 1998. Other articles identified which had not yet been indexed on Medline were also included.

The entire set of retrieved articles was reviewed, and those unrelated to pathogenesis, diagnosis, or management of SBS were discarded, as were those in which SBS was only peripherally mentioned, or in which SBS was unrelated to the original paper. Letters and brief correspondence were also discarded.

Because of time constraints, articles in non-English journals which lacked an English abstract were also generally excluded from assessment.

This reduced the initial list of 71 to 54 papers, which were reviewed, categorised and ranked according to the QER above. To these was added the important paper of Jayawant et al from the BMJ of December 5, 1998. The editorial was omitted, as it added nothing to the original paper, and drew conclusions unsupported by the paper reviewed.

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There was insufficient time to retrieve and review the majority of original articles, although some of the main papers were reviewed in full. The remainder were assessed using the author's abstract.

Each paper was assigned to one of four categories

1. *Randomised controlled trial (RCT)*
2. *Case series with or without controls (with date, series size recorded)*
3. *Single case reports*
4. *Other, including review articles, opinion pieces, articles on social implications, etc.*

RESULTS OF QUALITY OF EVIDENCE RATINGS.

54 papers or abstracts were reviewed

B. 1 WAS A RCT (34)

This trial was not relevant to this case, as it assessed a diagnostic technique (electroretinograph) which proved unsuccessful in diagnosis.

C. 26 WERE CASE SERIES

(1,2,7,9,11,13,14,15,18,19,26,28,29,30,33,36,39,42,45,46,47,48,49,50,52,53)

- 25 were retrospective studies, 1 was prospective
- In total, 307 SBS cases were claimed to have been assessed among the 23 papers in which numbers of SBS patients were provided, with a mean study size of 13 cases, and a median of 7 cases per series
- Selection criteria for SBS cases was unstated in 12; based on presumption or suspicion in 10; and confirmed in 4.
- 2 studies had appropriate control groups, 3 had inappropriate control groups, and 21 were case series without control groups.

D. 12 WERE CASE REPORTS (3,4,5,8,10,17,22,24,31,32,51,55)

- Retinal pathology in suspected SBS - 5 cases
- Blunt head injury at autopsy - 1 case
- SDH and RH as a result of fall and chest compression - 1 case
- Shaking causing traumatic aneurism - 1 case
- AV malformation, not SBS, as cause - 1 case
- Intentional asphyxia and shaking of 15 week old baby - 1 case
- MRI value in diagnosis - 1 case
- Raised ICP as cause of RH - 1 case

E. 15 WERE "OTHER" PAPERS (6,12,16,20,21,23,25,27,37,38,40,41,43,44,54)

- Historical reviews of shaken baby syndrome - 10 papers
- Opinion pieces - 3 papers
- Social issues and shaken baby syndrome - 1 paper
- Review of imaging in SBS (CT vs MRI) - 1 paper

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F. RESULTS

The RCT was unrelated in any aspect of diagnosis and care in this case, and reviewed a method of assessment of the retinae which proved to be unsuccessful.

Of the case series, the flaws noted above are relevant. All but one was retrospective, and all but 5 had no control population to compare cases to. Three of those that did include controls, chose inappropriate controls (head impact trauma, etc). This shortcomings should have excluded these studies from the literature review (as they do not fulfil criteria for inclusion). Given the difficulties inherent in assessing of SBS, and of identifying appropriate control groups, I have included these as QER III-2.

In studies with confirmed (ie admitted or observed) trauma and SBS, there were few common findings, apart from the presence of SDH accompanied by RH in 80% of examined cases. Some papers attempt to measure other risk factor, and the Jayawant paper is noteworthy in this respect.

Finally, the "other" papers do little but summarise opinions and summarise past data. Such paper do not add to the quality of understanding of the condition, nor are they necessarily accurate in what has become a rather emotionally charged area of research and endeavour.

I would address the issue of the apparent preponderance of conclusions of the medical papers, especially the historical reviews and position papers produced.

I am assessing the quality of evidence, not the predominance of opinion. The issue of the evidence for shaken baby syndrome appears like an inverted pyramid, with a very small data base (most of it poor quality original research, reviewing medical records, and without appropriate control groups) leading to a very broad body of convergent opinion. The repetition of poorly acquired information cannot improve the quality of evidence in this setting.

G. DATA GAPS IDENTIFIED

There exist major data gaps in the medical literature regarding SBS. These are summarised as:

- *Lack of clear definition of cases - there is an urgent need for standard criteria, to identify certain cases for the purpose of homogeneity in trials and identification of the unique features of SBS as opposed to other abuse, other medical conditions, and normals. I note a recent article in New Scientist suggesting that tests being developed in the USA may be able to differentiate SBS from other disorders. This is required (if possible) to ensure a firm and accepted way of categorising SBS cases in the future.*
- *Lack of useful and specific laboratory or other markers proven to identify SBS.*
- *Poor definition and quantification of the social and family risk factors to provide guidance on likelihood of abuse for a given set of circumstances*
- *There is a strong need a checklist/or other diagnostic or management tool to assess cases and to quantify index of suspicion of shaking*

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I.

SUMMARY

There is no evidence on the subject of shaken baby syndrome that exceeds QER III-2. This means that there is inadequate scientific evidence to come to firm conclusion on most aspects of the diagnosis, treatment or other matters pertaining to shaken baby syndrome.

The majority of evidence is QER IV, opinions which shed no light upon shaken baby syndrome, do not add to knowledge, and focus often on areas of prior interest or convictions of the author. Many of these authors have repeated the logical flaw, that if RH and SDH are nearly always seen in SBS, that the presence of RH and SDH "prove" that a baby was shaken intentionally.

The remainder of papers are QER III-3, and as noted above, the inclusion of case series without controls would normally not occur.

Thus, the data available in the medical literature are inadequate to support any standard case definitions, any standards for intervention or diagnostic assessment.

At present, there exists serious data gaps, flaws of logic, inconsistency of case definition, and a serious lack of tests which may discriminate NAI cases from naturally injuries.

There is an urgent need for properly controlled, prospective trials into shaken baby syndrome, using a variety of controls. Until such studies are complete, published and replicated, the current opinion on the link between SDH/RH and shaken baby syndrome cannot be sustained.

Signed



Dr Mark Donohoe
Refs included

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Appendix I

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* selected according to criteria described in text of appendix I

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Phyllis Spurgeon

From: Gary Udashen [gau@sorrelsudashen.com]
Sent: Wednesday, February 15, 2006 7:27 AM
To: ps@sorrelsudashen.com
Subject: Fwd: Ovid Results

Begin forwarded message:

From: "Sperling, Carrie B." <csperling@ou.edu>
Date: February 14, 2006 2:23:39 PM CST
To: "Gary Udashen" <gau@sorrelsudashen.com>
Subject: FW: Ovid Results

Carrie Sperling
Legal Research and Writing
University of Oklahoma College of Law
300 Timberdell Rd.
Norman, OK 73019
(405) 325-8007

-----Original Message-----

From: Ovid_Online@ovid.com [mailto:Ovid_Online@ovid.com]
Sent: Tuesday, February 14, 2006 1:21 PM
To: Sperling, Carrie B.
Subject: Ovid Results

Ovid Technologies, Inc. Email Service

Results: The American Journal of Forensic Medicine and Pathology

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Volume 25(2), June 2004, pp 89-100

A Biomechanical Analysis of the Causes of Traumatic Brain Injury in
Infants and
Children
[Review]

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2/15/2006

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Outline

Abstract:

Biomechanics

Loading characteristics

Injury parameters and criteria

Scaling and impulsive loading

Deformation and failure characteristics of objects

Differences in adult and infant skull properties and the response to
impact
and impulsive loads

Analysis of impacts due to falls

Recent studies

Abuse

CONCLUSIONS

ACKNOWLEDGMENTS

REFERENCES

Glossary

Graphics

Figure 1

Figure 2

Figure 3

Equation (Uncited)

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Table 1

Abstract:

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There is significant disagreement among medical professionals regarding the mechanisms for infant brain injury. This disagreement is due in part to the failure by some to acknowledge and incorporate known biomechanical data and models into hypotheses regarding causes. A proper biomechanical understanding of the mechanisms of traumatic brain injury (TBI) challenges many published and testified assumptions regarding TBI in infants and children.

This paper analyzes the biomechanical relationship between the causes of TBI in infants and children, and their physiological consequences. Loading characteristics, injury parameters and criteria, scaling, failure characteristics, differences between infants and adults, and impact due to falls are described and discussed in the context of the laws of mechanics. Recent studies are critiqued with reference to their contribution to an understanding of brain injury mechanisms. Finally, methods for improving our currently incomplete knowledge of infant head injuries, and their mechanisms, consequences and tolerances are proposed. There is an urgent need for close collaboration between physicians and biomechanicians to objectively and scientifically evaluate infant head injuries to further define their mechanical bases, and to assist in their diagnosis and treatment.

Biomechanicians and physicians evaluate trauma in fundamentally different ways. A biomechanician constructs or accepts a particular system, obtains its physical and geometric characteristics, applies a specified and quantifiable input (load), and then determines the output using experimental, analytical, and numerical techniques. A physician sees the end product of signs and symptoms, and relies primarily if not exclusively on experience and observational case material to diagnose and treat. A biomechanician traces a continuous path from cause to effect using the laws of nature, tries to determine the specific mechanism of an injury, and attempts to either establish or eliminate an

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ultimate mechanical cause. A physician treats the physiological alterations due to an injury, and does not usually need to validate the diagnosis with a controlled experiment prior to making a decision to initiate treatment.

Recent advances in the quantitative characterization of the material and structural properties of the developing infant brain and skull permit the biomechanician to study the differences between traumatic brain injury in infants and adults.¹⁻⁶ The findings suggest that understanding the unique age-dependant properties of the developing brain and skull is critical for determining both impulsive and impact loading thresholds. New and continued research, including pediatric injury models, will play a vital role in evaluating infant traumatic head injury.⁷ Collaboration between biomechanicians and physicians will provide a foundation for developing improved clinical, diagnostic, preventive, therapeutic, and rehabilitative strategies to address the unique problems of pediatric head injury.

Biomechanics

Biomechanics is the application of the science of mechanics to biologic systems, whether plant or animal.^{8,9} Mechanics is defined as the consequences of the application of forces and couples (a set of equal, parallel and oppositely directed forces) to one object or a system of objects (solid, liquid or gas). A solid object may be considered analytically as a particle (a point in space that has mass, and that resists motion); as a group or system of such particles; or as a single solid body that may be either rigid or deformable.

Skull and brain motion and the forces causing them are governed by Newton's Second Law, Force = mass times acceleration ($F = ma$). The displacement of the head (as an object with mass) can be described as planar or as occurring in space as defined by motion in one or all 3 of the X-, Y-, and Z-axes. The displacements are governed by Newton's Law and constraints, and can be extended to provide an impulse-momentum and a work-energy relation. The neck is a constraint to this motion.

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Loading characteristics

Traumatic brain injury (TBI) in infants, children and adults is caused by one of 2 mechanisms: (a) Impulsive Loading, when the head moves as the result of motion imparted to some other part of the body ("whiplash", Figs. 1a and 1b); and (b) Impact Loading, where the head either strikes a stationary object (Fig. 2a) or is struck by a moving object (Fig. 2b). These events are mechanically distinct and separate and they have different consequences. Both actions cannot occur simultaneously, although they may happen sequentially.

FIGURE 1. Impulsive loading (a) Rear loading (b) Front loading.

FIGURE 2. Impact loading (a) With a fixed object (b) With a moving object.

Impulsive loading of an unsupported head will cause it to rotate about some point of the cervical spine, from the occipital condyles to C7/T1. In such a rotation, the skull will move at a different rate from the brain, which lags behind because the brain and skull are not rigidly linked and force is transmitted to the skull prior to the brain, in the same way that a car responds to an impact before a passenger. This differential displacement may produce tensile failure of the bridging veins, which occurs on the average when they are stretched 30% beyond unloaded length.^{10,11} Further, at a given input, injury due to impulsive loading typically decreases from the cortex towards the base of the

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brain.^{12,13} There are also regional and directional differences of brain injury type and distribution from impulsive loading, and differences due to vessel orientation.¹⁴⁻¹⁶ Sagittal plane acceleration at sufficient magnitude usually causes a subdural hematoma (SDH), while coronal plane acceleration at sufficient magnitude usually results in traumatic axonal injury (TAI, which may be focal or diffuse [DAI]).¹⁷ Most studies have used a single applied load, but a recent investigation of repetitive loading of rats showed increasing damage with successive load application after significant periods of quiescence.¹⁸

Impact, in contrast, is the collision of 2 solid objects at a velocity sufficient to cause observable effects.¹⁹ Impact loading is fundamentally different from impulsive loading. An impact produces: (a) a contact phenomenon in one or both of the colliding objects, such as a scalp contusion or skull fracture; and (b) the transmission and reflection of pressure waves into the system (Fig. 3), for example, the contracoup effect of skull deformation²⁰ or cavitation.²¹⁻²³ If there is no contact phenomenon or wave propagation, the event is not an impact. Slamming a baby or an adult's head into a pillow is not an impact because there is no wave propagation: the pillow simply gives way, absorbing and diffusing kinetic energy of the moving head such that very little energy must be dissipated by the head and its contents.

FIGURE 3. Contact phenomenon and wave propagation in impact to the head.

The impact of a rigid skull against a nonyielding surface always causes both translational and angular acceleration of the brain unless the force is transmitted exclusively through the center of mass. The relative contributions of the impact-induced translational and angular acceleration components,

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and their magnitude will determine whether a subsequent injury is primarily focal, primarily diffuse, or a combination of focal and diffuse. The path to the impact ("preimpact impulsive loading", such as a fall from a moving swing, or a "slam" following a "shake") is irrelevant and does not contribute to the injury or its characteristics.²⁴⁻²⁶

Injury parameters and criteria

Kinematic (motion) parameters such as acceleration (G's) are usually used to define injury thresholds. It is relatively simple to measure linear acceleration, a, in contrast to a quantity such as deformation that can be directly associated with injury. However, kinematic parameters are an incomplete description of the event and may be significantly misleading. Unfortunately, the current federally mandated standards,²⁷ supplemented by those of private organizations such as the American National Standards Institute²⁸ and the Snell Foundation,²⁹ base head injury tolerance on either the peak acceleration, the acceleration-time record, or a function of the acceleration history. The latter, called the HIC (Head Injury Criterion), is defined as

Equation (Uncited)

where t_1 and t_2 are any 2 points on the acceleration curve. If the HIC is less than 1000, the criterion predicts that there will be no irreversible injury.³⁰

These standards specify linear acceleration as the tolerance parameter, although angular acceleration produces a different and more significant injury pattern.^{31,32} Tolerance based on linear acceleration resulted from the pioneering work of

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Gurdjian.^{33,34} His curve, known as the Wayne State Tolerance Curve (WSTC), is based on a number of assumptions, including the equivalence of linear skull fracture and the onset of concussion, and the direct extrapolation of the results from cadavers to living humans. The WSTC and others³⁵ do not differentiate between age, sex, or size, and were expected to apply to infants and children as well as adults. However, this extrapolation is almost certainly invalid because the cerebral mechanical properties and even scaled geometry of infants is quite different from that of adults.¹⁻⁷

Regardless of the utility of the HIC for defining limits of translational acceleration, other criteria have been proposed.³⁶ A separate criterion is also needed for rotational acceleration and for a combination of rotation and translation occurring simultaneously (as is almost always the case for biologic systems).³⁷

Sturtz established linear acceleration head tolerance levels for children by reconstructing pedestrian-automobile impacts.^{38,39} He determined that 83g was the limit for the anterior/posterior acceleration when the acceleration lasted more than 3 milliseconds. He also concluded that a peak acceleration of 70g was associated with completely reversible injury, and that 110g was associated with 25% irreversible injury. These limits correspond to HIC values of 350 and 600, respectively, for a 6-year-old child dummy⁴⁰).

The biofidelity and motion of the Child Restraint-Air Bag Interaction (CRABI) anthropometric dummy⁴¹ have been studied by subjecting the dummy to linear and angular acceleration.⁴² The author suggested limiting HIC values for the 6-month-old infant of 121 with an acceleration duration of 22 milliseconds (a peak tolerance of 32g), if the values are scaled from adult dummy values of HIC = 1000, an acceleration duration of 15 milliseconds, and a peak acceleration of 85 g. However, the CRABI dummy may not provide adequate biofidelity at impact levels producing significant injury.⁴² Experiments using other surrogates were

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somewhat inconclusive, but indicated no significant difference in tolerance levels between children and adults,^{43,44} with values in the range of those found by Sturtz.³⁹

Gennarelli and Thibault established angular acceleration tolerances by subjecting baboons to severe rotational acceleration replicating automotive impacts.^{13,17,32} These experiments were designed to isolate the rotational component of brain acceleration caused by an impact, not to study "whiplash". The measured angular acceleration corresponding to the observed injuries, from concussion to SDH to DAI, were extrapolated to humans using scaling relations discussed below. These extrapolations were also used for the first of only 3 published scientific experiments conducted to measure the acceleration levels produced by shaking and by impact, and to predict the likely outcome in an infant.⁴⁵ The results (Fig. 4) plot angular acceleration as a function of the change in angular velocity, with injury thresholds scaled from primate experiments to a 500 g brain mass. Mean peak tangential accelerations for "shaking" were 9.3 g, while those for "impact" were 428 g, 46 times greater. These impulsive loading and impact experiments were repeated with an infant dummy that had a deformable skull.^{46,47} In these studies, the ratio of peak impact acceleration to impulsive loading acceleration was reduced from 46 to 39, as expected with a deformable skull model.

FIGURE 4. Angular acceleration as a function of angular velocity scaled to a 500 g brain mass, showing thresholds of concussion, SDH and DAI for both shaking and impact.⁴⁴ (Reproduced with permission from Duhaime A-C, Gennarelli TA, Thibault LE, et al. The shaken baby syndrome: a clinical, pathologic and biomechanical study. J Neurosurg. 1987;66:409-415.

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The low load level from shaking was substantiated by experiments in our Berkeley laboratory using an anthropometric dummy shaken by a variety of individuals. "Shaking" produced frequencies from 3-5 Hz, with associated total displacements from 102-152 mm (4-6 in). If the excursion and frequency are modeled as "simple harmonic motion",⁴⁸ a repetitive movement at a uniform rate from an equilibrium position with an amplitude, A, half (51-76 mm [2-3 in]) of the total displacement, the motion approximates an actual "shaking". Using this model, the maximum linear acceleration, $a_{max} = A[\omega]^2$, where $[\omega]$ is the angular velocity, was 7.7 g, slightly less than that found in the previous tests.⁴⁵⁻⁴⁷ When the actual digital camera data rather than the model were analyzed, the result was 15 g, higher than the model because the real-time motion is not that of a rigid-body.

Two sets of whiplash tests on anesthetized baboons,^{31,49} modeling a rear-end vehicular collision, caused acute SDH and spinal cord injuries with angular velocities above 500 rad/s and angular accelerations of more than 10 krad/s². (10 krad/s² is 10,000 ft/s², or 155 g's, at a radius of 1 foot.) These values are typical of head accelerations under vehicular impact conditions. The results of these experiments have been cited incorrectly⁵⁰⁻⁵² to support the mechanism for Shaken Baby Syndrome (SBS), the authors apparently not understanding that the results replicated the effects of a 48.3 km/h (30 mph) vehicular impact, not a 9.3 g "shake".

Scaling and impulsive loading

Different sized brains do not have the same injury thresholds. However, it is possible to convert or scale brain injury thresholds associated with impulsive loading from many animals to humans. These species relationships are based on an empirically verified equation, derived from theory, where the ratio of the

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accelerations is equal to the inverse of the brain mass ratio raised to the 1/3 power for linear acceleration and the 2/3 power for angular acceleration (Fig. 5).^{53,54} Scaling assumes complete material property, structural, and geometric similarity between the various systems compared. The head of an infant is smaller and geometrically unlike that of an adult.⁵⁵⁻⁵⁷ The structural properties of the infant skull (case of deformation and decreased threshold to fracture), and the mechanical properties of the infant brain are also different from those of an older child or adult.^{5,46,58,59} These actual and potential differences between adult and infant brain structural and mechanical properties mean that impact-induced acceleration tolerances for nonhuman adult primates should not be scaled to human infants.

FIGURE 5. Concussion tolerance as a function of angular acceleration and brain mass.⁵² (Modified and reproduced with permission from Ommaya AK, Yarnell P, Hirsch AE, et al. Scaling of experimental data for cerebral concussion in subhuman primates to concussive threshold for man. In: Proc 11th Stapp Car Crash Conf New York: SAE; 1967: 47-52. SAE Paper 670906.)

Deformation and failure characteristics of objects

A SDH is usually caused by rupture of the parasagittal bridging veins. The mechanical and failure behavior of these vessels have been determined by load tests that provide either force-deformation or stress-strain relations up to rupture. Unidirectional stress is force per unit area, $[\sigma] = F/A$, while deformation (strain) may be through extension, compression, or "shear". Mathematically, uniaxial strain $[\epsilon] = ([\Delta] L/L_0)$ where $[\Delta]L$ is the change in length and L_0 is the original length.^{8,48}

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The behavior of all solid materials under loading conditions is characterized either by a relationship between stress and strain (and possibly time), a constitutive equation, or by a load-deformation curve, a structural designation. Solid material behavior is characterized as elastic, or time-independent and reversible, when a substance subjected to a force immediately returns to its original shape upon unloading along the same path as the loading curve. The behavior is viscoelastic when internal energy dissipation significantly delays the return of the deformation to its original state upon unloading and/or the unloading path is significantly below the loading curve. It is plastic when a substance (such as clay) retains a permanent deformation after load removal. Most biologic tissues, including brain, are viscoelastic and their behavior depends on the rate of load application. Only teeth, nails, and adult bone have nearly elastic behavior before failure.

The critical load is that where mechanical (structural) failure is produced, although physiological (functional) disruption may occur at lower levels. The critical value is the ultimate strain, $[\epsilon]_u$, corresponding to an ultimate stress, $[\sigma]_u$, where there is total mechanical disruption (fracture of the skull or rupture of the bridging veins). The likelihood of bridging vein rupture also depends on the orientation of the vessels to the superior sagittal sinus. Veins anterior to the midfrontal pole drain posteriorly to join the sinus in the same direction as its flow, and are subject to maximum extension strain only with a frontal impact. Vessels at the midfrontal pole enter the sinus perpendicular to it. Veins posterior to the midfrontal pole drain anteriorly into the sinus, in the direction apposite its flow, and experience maximum extension strain with an occipital impact.^{10,11,60,61}

An example of a set of nonlinearly elastic relationships of vessels under slow loading conditions is shown in Figure 6. 62,63

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FIGURE 6. Quasi-static stress versus stretch behavior for various fresh cortical arteries and veins.⁵⁹ (Reproduced with permission from Monson KL, Goldsmith W, Barbaro N, et al. Static and dynamic mechanical and failure properties of human cerebral blood vessels. In: Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems. New York, ASME; 2000. AMD 246/BED 49:255-65.)

Differences in adult and infant skull properties and the response to impact and impulsive loads

The mechanical characteristics of the infant and adult skull are not the same.

The adult skull is only slightly deformable prior to fracture. The infant skull is not rigid, and should be considered as a segmented unit of loosely associated curved plates with interspersed soft membranes (sutures and fontanelles).^{55,64}

Thibault and Margulies^{5,6,65,66} compared the mechanical properties of the skulls of human infants and adults to those of infant and adult pigs. They found significant variation in the failure stress of the skull of the neonate, the young child, and the adult, with an increase in stress to fracture of more than a factor of 10 from the newborn to the adult (Fig. 7). The variation in the elastic modulus, E, showed a 10-fold increase (Fig. 8), supporting nearly identical conclusions from earlier tests.^{40,67,68}

FIGURE 7. Skull failure stress for the neonate, young child and adult.⁸ (Reproduced with permission from Ommaya AK, Goldsmith W, Thibault L. Biomechanics

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and neuropathology of adult and pediatric head injury. Br J Neurosurg. 2002;16: 220-242.)

FIGURE 8. Elastic modulus of human cranial bone versus age. (Created by Kirk L. Thibault, PhD, from data in the studies referenced.)

The Consumer Products Safety Commission (CPSC)⁵⁶ has published a compendium on the geometric properties of the infant head. An earlier work indicated substantial difference in the vasculature of infants and adults.⁵⁷ The neonates had thinner and fewer vessels than the mature cortex,⁶⁹ the blood/brain barrier was incompletely developed, and the infant blood cerebral blood flow and oxygen consumption were more than twice that in adults.

These structural differences cause the injury mechanism for an infant to be fundamentally different from that of an older child or adult. Impact loading of the compliant infant skull/brain unit produces potentially damaging levels of strain within the entire structure. Deformation, not impact-induced angular acceleration, is the critical factor. Nonimpact loading ("shaking") may result in strains of the neurovascular structures, but there is no associated skull deformation. Biomechanical studies have demonstrated that the head accelerations generated by shaking are below the thresholds for traumatic DAI, SDH, and even concussion. If one could "shake" an infant or a child, or an adult for that matter, vigorously enough to cause traumatic DAI or SDH, there will be significant structural neck damage, including the craniocervical junction (F.A. Bandak, personal communication).⁷⁰⁻⁷¹ Shaking simply does not generate accelerations that exceed any known injury tolerance values for

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traumatic brain injury.

The material and structural properties of the skull and brain are age-dependant.

The transition from the predominately deformation-mediated impact response in an infant to a predominately acceleration (impulsive)-mediated response in an older child or adult is a continuum. It is not possible, with today's data, to state a specific age at which the final change occurs. In vivo and surrogate biomechanical experiments to further define the parameters of age-dependency must be assisted by various imaging technologies including MRI, a careful neurologic examination for signs of cervical spinal cord or brain stem injury in a child who is living, and a complete and careful postmortem examination including posterior neck dissection if death occurs.

Analysis of impacts due to falls

The linear impulse-momentum relation derived from Newton's Second law applied over time can be used to analyze an impact caused by a fall. The relationship states that the area under the force-time (F-t) curve is equal to the change of linear momentum; in practice, the product of mass, m , times the change of velocity, $[\Delta]v$.^{19,48} For contact events, the maximum force generated can be closely approximated by the expression $F_{max} = 2m[\Delta]v/[\tau]$, where $[\tau]$ is the duration of contact.⁷² If a 0.91 m (3 ft) tall child falls by backward rotation about the soles of his/her feet, the translational impact velocity is 4.24 m/s (13.9 ft/s) at the occiput, and the angular impact velocity is 4.63 rad/s. Our Berkeley laboratory determined that contact duration $[\tau]$ is 3-7 milliseconds by dropping a weight-adjusted cadaver skull onto the edge of a hardwood stair step. If only the impact of the head produces the contact force (the weight of the body does not contribute), the contact time is taken as 5 milliseconds and the head weighs 22.4 Newtons (N) (5.3 lb), 20% of the body weight of 112 N (26.4 lb), the peak force is 4070 N (915 lb) from the

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linear impulse-momentum relation, assuming a triangular force profile. This is a peak acceleration of 173 g, nearly sixteen times greater than would be obtained by shaking and twice as great as the tolerance limit suggested by Sturtz.³⁹ These linear acceleration values approach those obtained from the previously described actual experiments;⁴⁵⁻⁴⁷ the small differences are most likely due to variation in surface characteristics or a conservative assumption for the contact time in the above analysis.

There has been sworn testimony in courts of law by expert witnesses who state that trauma caused by shaking is equivalent to a fall from a two-story (or higher) window onto the pavement.⁷³ If such a fall is head first with the body in a vertical or near vertical position at impact, the forces on the head can be calculated from the linear impulse-momentum law. Assuming that the weight of the child is 66.7 N (15 lb), that the fall height is 5.63 m (18 ft), and that the contact duration is a very conservative 10 milliseconds, the impact velocity will be 10.37 m/s (34 ft/s), and the peak contact force 14,190 N (3167 lb). This exceeds by at least an order of magnitude the force that can be exerted by shaking, and at least 3 times that considered from the data of Gurdjian³⁰ as the human tolerance limit. The analogy of "shaking" injury to that from a two-story fall is not justifiable.

It has also been stated that falls from low heights do not produce significant injury or death.⁷⁴⁻⁷⁶ However, Mohan et al⁷⁷ analyzed 30 falls in children under the age of 10, and reconstructed 6 of them using the MVMA Two-Dimensional Crash Victim Simulator computer model. The authors concluded that falls as low as 2 meters may cause serious injury or death.

Plunkett documented 18 fatal falls from heights of 0.6 to 3 m (2-10 ft).²⁴ One of these falls was coincidentally videotaped, permitting an approximate analysis of the contact loads. A 23-month-old girl who weighed 129 N (29 lb) and

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was
 0.838 m (33 in) tall fell from a play structure onto a 10 mm (0.39 in)
 thick
 carpet without foam backing covering a concrete floor. She had lost her
 grip on
 a rail when she was in a nearly horizontal position approximately 1.07 m
 (42 in)
 above the ground. She struck the ground first with her outstretched
 hands and
 then with her right upper frontal forehead, followed by her right
 shoulder (Fig.
 9). Although alert immediately after the fall, she became unconscious
 within
 approximately 5 minutes. She was taken to a tertiary care hospital where
 a 100
 mL right-sided SDH was immediately evacuated. The attending medical
 staff
 documented extensive bilateral retinal hemorrhage (RH) following the
 surgery.
 Postoperatively, she developed refractory cerebral edema and was removed
 from
 life support after 1.5 days. An autopsy showed a small residual right
 SDH,
 cerebral edema with herniation, and a 40 x 45 mm (1.58 x 1.77 in) right
 frontal
 scalp contusion. There was no skull fracture.

FIGURE 9. Idealized contact position and loads in the fall of a 29
 lb
 (12.9K) child from a height of 42 in (1.07 m).

Her unsupported weight caused rotation about her feet until her body was
 at an
 angle of approximately 45[degrees] from the horizontal, with her head
 and neck
 inclined at approximately 30[degrees] to the horizontal. Her feet then
 disengaged the play structure and she fell freely with her center of
 gravity
 dropping 0.483 m (19 in) until she struck the carpet. If the moment of
 inertia
 (the property of an object to resist rotation) taken at the center of
 mass, G ,
 is idealized as a uniform cylinder with a radius of 101.6 mm (4 in), her
 moment
 of inertia about her feet is 3.116 N-m-s² (27.57 lb-in-s²).⁴⁸ The impact
 velocity due to rotation, using a number of simplifying assumptions, is

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4.36 m/s (14.3 ft/s) whose vertical component is 3.78 m/s (12.4 ft/s). The concurrent velocity due to the vertical motion of the center of gravity in the fall is 3.05 m/s (10 ft/s), so that the impact velocity of the head is 6.83 m/s (22.4 ft/s) (compared with 4.57 m/s [15 ft/s] if the body remained entirely horizontal). This calculation ignores the braking effect of the outstretched arms, so that the likely impact speed of the head was of the order of 4.57-6.10 m/s (15-20 ft/s).

Since the skull, scalp and carpet were not available to measure compliance, the contact duration will be conservatively assumed to be 10 milliseconds. The child's weight distribution will be assumed to be 107 N (24 lb) for torso, legs and arms, 4.45 N (1 lb) for the neck and 17.8 N (4 lb) for the head. The 107 N (24 lb) component will be resolved along and perpendicular to the spine (the centerline of the body); this component, further resolved, is transmitted along the neck to the head, and the full weight of the head contributes to the impact event. This results in an equivalent vertical force at the contact point due to the weight components of 60 N (13.5 lb). The peak impact contact force F_m is calculated from the adjusted linear impulse-momentum equation, using both the equivalent weight of 60 N (13.5 lb) and the full child's weight of 129 N (29 lb). The clockwise movement of her head is small and will be ignored. The peak forces and corresponding maximum compressive stresses, assuming that contact occurred over the entire area of the contusion, are (Table 1).

TABLE 1. Impact Force and Stress

This child did not have a skull fracture (consistent with a

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well-distributed impact load against a flat surface), and the area of her scalp contusion was less than 2.25 in². Her skull failure stress was approximately 16-20 MPa (Fig. 7). Her maximum skull stress computed for a duration of 10 milliseconds is less than 16-20 MPa for both sets of conditions used in the calculations. Although the peak compressive stress is not directly related to the tensile failure limit of the parasagittal bridging veins, this limit of 3.5 MPa is of the same order of magnitude.

Finite element modeling (FEM) of heads subjected to various types of impact and impulsive loading supports this type of analysis.^{68,78} However, until validated by appropriate experiments, the FEM results must be interpreted cautiously.

Recent studies

Geddes et al did the first rigorous analysis of the infant brainstem in presumed nonaccidental head injury.⁷⁹ They identified specific neuropathological findings in head injury for 53 infants and children, and found statistically significant patterns of age-related injury. The group of 37 infants 20 days to 9-months-old tended to have injuries limited to the head, including skull fracture (43%). Twenty-six of the 37 (70%) had SDH. The SDH was a "thin-film" in 21 of the 26 (84%). Eleven (30%) of the 37 infants had immunohistochemical evidence for axonal damage at the craniocervical junction. Only 2 infants had traumatic diffuse axonal injury (DAI). Children thirteen months or older tended to have larger SDH, and if there was traumatic axonal damage, the injury patterns were similar to those reported in adults. The authors concluded that traumatic DAI is uncommon in children thought to have inflicted head injury.

In a second study, these authors compared the neuropathological findings in the younger group of 37 infants to a control group of 14 similarly aged infants who died of other causes.⁸⁰ The most common finding in the study group was global

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hypoxic damage (84%). Two cases had traumatic axonal injury, and both had severe contact head injuries with skull fractures. Epidural cervical hemorrhage, and focal axonal brainstem and cervical nerve root damage, was found in 11 cases, with none in the control group, suggesting relative vulnerability at the infant craniocervical junction. The authors concluded that the lack of widespread severe axonal damage in the infant could be explained in one of 2 ways: either the nonmyelinated axons of the immature brain are less susceptible to damage during traumatic loading, or in "shaking type injuries" the brain is not exposed to the forces necessary to cause traumatic DAI. Because of the trivial nature of the brain stem pathology in a few of the cases, coupled with a lack of damage to soft tissues in the neck, the authors suggested that hyperextension/hyperflexion at low loading levels, below those necessary to cause diffuse brain damage, may injure nerve fibers at the craniocervical junction. The resulting apnea leads to severe hypoxia and cerebral edema, and the immediate signs and symptoms may mimic those previously thought due exclusively to parasagittal vessel failure caused by violent head rotation.

Margulies and Thibault's study emphasized the critical role of skull deformation in infant impact head injury by measuring infant skull and suture properties, and modeling differences between infants and adults with regard to the consequences of impact loading. They first confirmed that infant pig and human skull and suture properties were comparable, then measured infant pig cranial bone and suture failure using tensile and three-point bending. They found that the elastic modulus, ultimate stress, and energy absorbed to failure increases, and ultimate strain decreases, with age for both skulls and sutures. The authors then constructed 2 finite element models of a one-month-old infant head, using the above-determined infant values for one and adult values for the other. When the models were impact loaded, the skull and brain of the infant model underwent larger cranial shape changes and had a more diffuse

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pattern of brain distortion than the adult model. Dynamic herniation of the brainstem through the foramen magnum as a result of these shape-change induced deformations during impact, or quasi-static herniation of the brainstem during secondary brain swelling, may cause focal traumatic axonal injury mimicking "shaking"/hyperextension.

Abuse

Either abuse or an accident may cause head injury in an infant or child.^{81,82} However, it is not possible to differentiate a deliberate impact from an accidental fall under the same mechanical circumstances (speeds, surfaces, configurations) by biomechanical analysis since the mechanism and injury patterns will be identical.

There are other "hallmarks" of "nonaccidental" infant head trauma that need to be critically evaluated. For example, Greenwald⁸³ and the American Academy of Ophthalmology⁸⁴ have stated that retinal hemorrhage (RH) with particular characteristics is "proof" of shaking. Greenwald and others^{52,83,85} state that the mechanism for RH in SBS is impulsive loading, with vitreous traction splitting the retina. However, external rotation of the eye as would occur with "shaking" (with a moment of inertia about C4-5) is curvilinear not rotational. For internal rotation (the eye rotating about its own center of mass) to cause traumatic injury, scaling suggests that the level of acceleration would need to be greater than 100,000r/s², or 6250g at a radius of 3/8 in. Experimental data indicate that the actual mechanism for RH is functional or mechanical venous occlusion.⁸⁶⁻⁸⁹ RH of all types and distributions has been documented in ruptured vascular malformations,⁹⁰ increased intrathoracic pressure,⁹¹ bungee jumping,^{92,93} atypical lymphohistiocytic proliferations,⁹⁴ short falls,²⁴ anemia,⁹⁵ and severe contact head injury.^{96,97} The question is not whether shaking causes RH, but under what mechanical constraints (rate, etc.) does cerebral edema or other causes of venous occlusion result in RH?

Does new bleeding/"rebleeding" in an established SDH require proximate trauma?

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This question can be approached biomechanically, but there is little definitive information concerning the sequence of events. For example, the rate of efflux from various types of tears in cerebral vessels has not been quantified, nor has the rate of resorption of blood in the subdural or subarachnoid spaces been determined. The "natural history" of an acute SDH includes new bleeding without proximate trauma, and has been documented in a series of patients with acute SDH followed by computed tomography scanning.⁹⁸

All of the above and preceding questions demand an interdisciplinary effort involving physicians, biomechanicians, and other specialists to determine the actual unique, age-dependant mechanisms of pediatric head injury. The effort should be directed toward constructing a dummy with realistic head and neck characteristics and subjecting this device to controlled loading. The experiments should be paralleled by analytical and numerical studies of the physical events and extended to the cellular level.⁹⁹⁻¹⁰⁶ When acceptable correlation of predictions and tests is achieved, a major step will have been taken to resolve these issues.

CONCLUSIONS

1. It is usually not possible, based on the medical signs and symptoms, to determine if a given head injury is due to an accident or abuse. Therefore, it is critical that health care professionals who are asked to make this determination understand injury mechanisms, tolerance thresholds, and the limitations of a mechanistic approach.

2. Tolerance thresholds for infants, and especially those less than 3-months-old, should not be scaled from adult acceleration or deformation data.

3. The known mechanical properties of the infant skull permit construction of a biofidelic dummy that can be subjected to a variety of loading conditions. The results can be compared with established or future injury criteria, providing a distinctive database for assessing the mechanical cause of an injury.

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The
results of such experiments can be correlated with data from analytical
modeling
and/or primate experiments.

4. It is not currently possible to construct a biofidelic infant neck
because
the mechanical properties of the infant neck are not known.

5. There is an urgent need for close collaboration between physicians
and
biomechanicians to objectively and scientifically evaluate infant head
injury,
and to assist in determining the mechanical basis, diagnosis and
treatment of
infant head trauma.

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Glossary

1. Acceleration, a - The rate of change of velocity.
2. Angular acceleration, $[\alpha]$ - The rate of change of angular velocity. The acceleration of a rigid body about a fixed axis may be resolved into two components, tangential ($a_t = r[\alpha]$) and normal ($a_n = r[\omega]^2$) to the radius of rotation, r .
3. Angular velocity, $[\omega]$ - The rate of change of angular position. The linear velocity associated with angular motion is normal to the radius of the motion ($v = [\omega]r$).
4. Anthropometric - Accurately mimics actual human dimensions.
5. Biofidelic - Accurately mimics actual human properties.
6. Coronal plane - Side-to-side plane.
7. Constitutive equation - The relationship between stress and strain, and their rates, that defines the behavior of a solid under loading.
8. Couple - A set of equal and oppositely directed but non-colinear forces.
9. Density - Mass per unit volume.
10. Displacement - The distance that an object moves.

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- 11. Elastic modulus - The ratio of stress to strain in a linear stress-strain curve.
- 12. Failure - A stress or strain that does not allow a return to the normal physical state.
- 13. Finite Element Method - The numerical, approximate solution of problems in mechanics by subdividing the spatial and temporal fields into small finite parts using the assigned properties of the system. The validity of the solution depends on the validity of the input properties of the system.
- 14. Force, F - Mass times acceleration.
- 15. Impulsive loading - Motion at a distance from an applied force.
- 16. Impact - The collision of two solid objects resulting in demonstrable deformation, and propagation of a signal away from the point of contact.
- 17. Kilogram, kg - The unit of mass in the metric system.
- 18. Linear acceleration - Acceleration along a straight line.
- 19. Load - A force or moment that produces motion or deformation.
- 20. Mass, m - The property of an object that resists a change in velocity.
- 21. MVMA - Motor Vehicle Motion Analysis, a numerical method developed at the University of Michigan to examine the motion of vehicle occupants subsequent to impact.
- 22. Newton, N - The unit of force in the metric (kms) system. For purposes of this article, the Newton is used as an equivalent unit for mass to avoid converting the English unit of force (Pound) to the English unit for mass (slug).
- 23. Particle - A point in space that has mass.
- 24. Pascal, Pa - The unit of stress, force/unit area, in the metric system. One Pa = one N/m²; 1kPa = 1000Pa; 1 MPa = 1,000,000 Pa.
- 25. Pound, lb - The unit of force in the English (sfs) system.

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26. Quasi-static - Extremely slow rate of loading, for example, catching one's leg in an elevator door, or a finger in a vise.

27. Radian, rad - The unit of angular displacement. A radian is the radius of a circle stretched over its circumference. There are 2π rad in a circle, and each rad subtends an angle of 57.3 degrees. One krad = 1000 rad.

28. Sagittal plane - Anterior-posterior or posterior-anterior plane.

29. Scaling - Extrapolating the results from one set of experiments to another system based on size.

30. Slug, s - The English unit of mass. One slug = weight (in pounds)/32.2 at sea level.

31. Stress, $[\sigma]$ - Force per unit area.

32. Strain, $[\epsilon]$ - Change in length per unit reference length. Strain may be elongation, compression, or shear.

33. Ultimate stress - The stress at which a material fails structurally, associated with the largest load prior to failure.

34. Velocity, v - The rate of change of displacement.

Key Words: Traumatic Infant Head Injury; Shaken Baby Syndrome (SBS); Impact; Impulsive Loading

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STUDY REVEALS HOUSEHOLD FALLS MAY PRODUCE MORE SEVERE BRAIN INJURIES IN INFANTS THAN PREVIOUSLY THOUGHT

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PHILADELPHIA -- Using a specially designed, highly lifelike doll, researchers at the University of Pennsylvania have determined that rapid head rotations sustained when a baby's head contacts a hard surface during household falls may result in diffuse brain injuries. The findings call into question earlier assessments of the seriousness of such falls by young infants, previously viewed by some as unlikely to cause widespread brain injury.

The results appear in the July issue of the *Journal of Neurosurgery*.

"Previously falls were considered relatively benign, because the head was assumed to move in a linear path at the terminus of a fall," said Susan S. Margulies, associate professor of bioengineering at Penn. "Linear motions are most frequently associated with skull fractures and focal brain injuries, but it is primarily rotational movements that produce more severe diffuse brain injuries. We found that when the head contacted a firm surface before the body, significant rotational motions were produced."

The Penn investigators found that rotational deceleration -- rapid changes in velocity as the head contacts a hard surface and then violently rebounds -- increased with higher falls and harder surfaces. The largest rotational decelerations, however, were measured when volunteers intentionally struck the doll's head against a hard surface. These inflicted impacts resulted in decelerations dramatically higher than those from even a five-foot fall onto concrete.

The findings by Margulies and her colleagues may help abuse investigators differentiate accidental falls from injuries caused by the striking of a child's head against a surface. Brain injuries -- accidental and inflicted -- hospitalize or kill an estimated 150,000 children annually in the U.S.

"Traumatic brain injury is the most common cause of death in childhood, and child abuse is believed to be responsible for at least half of infant brain injuries," Margulies said. "While accidental falls are a frequent cause of pediatric trauma, they are also a common explanation given by caretakers in suspected abuse cases."

Margulies has been using anthropomorphic dolls to study infant head injuries since 1987. The sophisticated doll used in this experiment was designed to mimic the median body weight, weight distribution and size of a one-and-a-half-month-old infant. The dummy's neck was hinged to replicate the compliant neck of a young infant, and its skull and scalp were made of materials closely approximating the properties of a young infant.

A sensor on the doll's head measured changes in rotational velocity and acceleration. Such motions are known to cause a diffuse pattern of strains and injuries throughout the brain, but no previous experiment has compared the rotational motion of the head during falls and inflicted events.

An apparatus dropped the doll 134 times from heights of one, three and five feet onto common household surfaces: a concrete floor, quarter-inch-thick carpet padding and a four-inch-thick foam pad, similar to a crib mattress. In additional tests, volunteers also shook the doll vigorously and then struck its head against one of the same three surfaces. "We found that vigorous shaking of this infant model had effects similar to one-foot falls and falls onto foam, but inflicted impacts of the head onto hard surfaces produced significantly greater rotational decelerations and changes in velocity than those onto foam, vigorous shakes and even a five-foot fall onto concrete," Margulies said. "Separate studies have shown that larger rotational

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Study Reveals Household Fans May Produce More Severe Brain Injuries In Infants Than Previously Thought

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decelerations lead to more severe brain injuries. Based on this evidence, our data suggest that inflicted impacts are much more likely than falls or shaking to lead to brain injury."

Comparing the results with published data from animals and children, the Margulies group concluded that it was highly unlikely that vigorous shaking or falls onto a foam mattress from distances up to five feet would result in severe or fatal brain injuries; however, five-foot falls onto concrete appeared capable of causing serious brain injury. The researchers also concluded that inflicted impacts with a hard surface would likely produce subdural hemorrhage and possibly diffuse axonal injury. Results were inconclusive on the effect of intermediate-height falls onto concrete or carpet padding. Margulies cautions that extensions of the findings to estimate likelihood of injury are tentative because little is known about how the infant or toddler brain and skull responds to rapid rotational motions and impacts.

"Children are not just miniature adults," Margulies said. "Learning more about pediatric brain injuries will help us develop protective devices -- helmets, playground surfaces, car seats -- that better meet their specific needs."

Margulies was joined in this research by Michael T. Prange and Brittany Coats of Penn's Department of Bioengineering and Ann-Christine Duhaime of Hitchcock Medical Center in Hanover, N.H. The research was funded by the National Institutes of Health and the Centers for Disease Control and Prevention.



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Journal of Neurosurgery Abstract

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*Journal of Neurosurgery**Journal of Neurosurgery: Spine**Journal of Neurosurgery: Pediatrics*

July 2003 Volume 99 Number 1

Laboratory Investigations

Anthropomorphic simulations of falls, shakes, and inflicted impacts in infants

Michael T. Prange, Ph.D., Brittany Coats, B.S., Ann-Christine Duhaime, M.D.
and Susan S. Margulies, Ph.D.

Department of Bioengineering, University of Pennsylvania, Philadelphia; and
Division of Neurosurgery, Children's Hospital of Philadelphia, Pennsylvania

OBJECT. Rotational loading conditions have been shown to produce subdural hemorrhage and diffuse axonal injury. No experimental data are available with which to compare the rotational response of the head of an infant during accidental and inflicted head injuries. The authors sought to compare rotational deceleration sustained by the head among free falls, from different heights onto different surfaces, with those sustained during shaking and inflicted impact.

METHODS. An anthropomorphic surrogate of a 1.5-month-old human infant was constructed and used to simulate falls from 0.3 m (1 ft), 0.9 m (3 ft), and 1.5 m (5 ft), as well as vigorous shaking and inflicted head impact. During falls, the surrogate experienced occipital contact against a concrete surface, carpet pad, or foam mattress. For shakes, investigators repeatedly shook the surrogate in an anteroposterior plane; inflicted impact was defined as the terminal portion of a vigorous shake, in which the surrogate's occiput made contact with a rigid or padded surface. Rotational velocity was recorded directly and the maximum (peak-peak) change in angular velocity ($\dot{\theta}_{\max}$) and the peak angular acceleration ($\ddot{\theta}_{\max}$) were calculated.

Analysis of variance revealed significant increases in the $\dot{\theta}_{\max}$ and $\ddot{\theta}_{\max}$ associated with falls onto harder surfaces and from higher heights. During inflicted impacts against rigid surfaces, the $\dot{\theta}_{\max}$ and $\ddot{\theta}_{\max}$ were significantly greater than those measured under all other conditions.

CONCLUSIONS. Vigorous shakes of this infant model produced rotational responses similar to those resulting from minor falls, but inflicted impacts produced responses that were significantly higher than even a 1.5-m fall onto concrete. Because larger accelerations are associated with an increasing likelihood of injury, the findings indicate that inflicted impacts against hard surfaces are more likely to be associated with inertial brain injuries than falls from a height less than 1.5 m or from shaking.

KEY WORDS. brain injury, child abuse, diffuse axonal injury, subdural hematoma, children

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02/01/2006 08:47 AM

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- ☐ brain injury
- ☐ child abuse
- ☐ diffuse axonal injury ☐ search
- ☐ subdural hematoma
- ☐ children

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Phyllis Spurgeon

From: Gary Udashen [gau@sorrelsudashen.com]
Sent: Wednesday, February 15, 2006 7:27 AM
To: ps@sorrelsudashen.com
Subject: Fwd: Ovid Results

Begin forwarded message:

From: "Sperling, Carrie B." <csperling@ou.edu>
Date: February 14, 2006 2:23:29 PM CST
To: "Gary Udashen" <gau@sorrelsudashen.com>
Subject: FW: Ovid Results

Carrie Sperling
Legal Research and Writing
University of Oklahoma College of Law
300 Timberdell Rd.
Norman, OK 73019
(405) 325-8007

-----Original Message-----

From: Ovid_Online@ovid.com [mailto:Ovid_Online@ovid.com]
Sent: Tuesday, February 14, 2006 1:23 PM
To: Sperling, Carrie B.
Subject: Ovid Results

Ovid Technologies, Inc. Email Service

Results: The American Journal of Forensic Medicine and Pathology

(C) 2001 Lippincott Williams & Wilkins, Inc.

Volume 22(1), March 2001, pp 1-12

Fatal Pediatric Head Injuries Caused by Short-Distance Falls
[Articles]

Plunkett, John M.D

From the Departments of Pathology and Medical Education, Regina Medical
Center,
1175 Nininger Road, Hastings MN 55033, U.S.A.; Email:
plunkettj@reginamedical.com.
Manuscript received April 10, 2000;
revised September 15, 2000; accepted September 24, 2000.

2/15/2006

PAGE 222

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CERTIFIED BILL OF COSTS

THE STATE OF TEXAS §

§

COUNTY OF CAMERON §

I, Aurora De La Garza, Clerk of the District Courts of Cameron County, Texas,
do hereby certify that the foregoing is a true and correct account of the costs accrued in
the following entitled and numbered cause:

Cause Number: **07-CR-885-B-WR**

The State of Texas

§

IN THE **138th** JUDICIAL

VS.

§

DISTRICT COURT OF

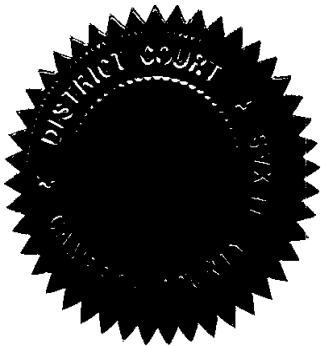
**MELISSA ELIZABETH
LUCIO**

§

CAMERON COUNTY, TEXAS

Given under my hand and seal of office in the **30TH** day of **MARCH**, 2011.

Aurora De La Garza
District Clerk



By: *Christina Tusa*
CHRISTINA TUSA, Deputy

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CLERK'S CERTIFICATE

THE STATE OF TEXAS §
 §
COUNTY OF CAMERON §

I, Aurora De La Garza, Clerk of the District Courts of Cameron County, Texas,
do hereby certify that the foregoing transcript contains true and correct original copies of
all proceedings as to the Writ of Habeas Corpus in:

Cause Number: **07-CR-885-B-WR**

WRIT I

The State of Texas

VS


MELISSA ELIZABETH LUCIO

As they appear on file and of record in this office.

Given under my hand and seal of said Court of Cameron County, Texas, on
Wednesday, March 30, 2011.

Aurora De La Garza
District Clerk
Cameron County




Christina Tusa
Deputy Clerk

0 0627